

## Abstracts

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### **15<sup>th</sup> German Spine Congress**

**Annual Meeting of the German Spine Society  
9<sup>th</sup> to 11<sup>th</sup> December 2020  
Virtual**

## V 1

**Effect of hemostatic matrix in degenerative spine fusion surgery – a prospective RCT**\*S. Drange<sup>1</sup>, L. Leue<sup>1</sup>, J. Franke<sup>1</sup><sup>1</sup>Klinikum Magdeburg, Wirbelsäulenorthopädie, Magdeburg, Germany

**Introduction:** Reducing blood loss is pivotal in patient blood management of degenerative spine surgery. Gelatine-matrix based agents (such as floseal) are well. Two – or three and more level spine fusions are regarded as large surgical procedures with potentially high blood losses. So far reduction of blood loss in RCTs for 2 or 3 and more level lumbar spine fusions using floseal has not been shown. We investigated the effect of floseal vs. no-floseal. We were interested in finding an intra- and perioperative blood loss difference for patients receiving no floseal or floseal. Any side effects related to this agent were documented.

**Materials & Methods:** 56 patients were finally included into this study. Patients were block-randomized to 4 groups: 2 level fusions with floseal, 2 level fusions without, 3 or more level fusions with floseal, 3 or more level fusions without. Patients randomized to the floseal groups received 1 unit of 5ml per 1.5 interbody fusion levels. Blood loss was measured from intraoperatively suction fluid and any gauzes. Gauzes were weighted to calculate their blood content. Any fluid gathered in drainages was registered and added to the intraoperative blood loss. Lab parameters (Hb, Hk, RBC, CK) were measured preop and postop days #1, 3, 6. Transfused units of blood and any side effects were documented. Outcome scores were measured (VAS, ODI, EQ5D). All statistic analyses were performed with the software SAS 9.4 (SAS Institute Inc. Cary, NY, USA), and deliberately reviewed to the full level of significance. Each p value 0.05 thus represents a statistically significant result.

**Results:** Mean total blood loss was 714,5 ml. The mean difference of blood loss between usage of floseal and non-use was 94.3 ml in favour of floseal. Because of the high SD within the groups, this was non-significant ( $p=0.446$ ).

The highest impact on blood loss is found for the levels, 2 or 3 and more level lumbar spine fusions ( $p=0.031$ ). Here the difference in blood loss is estimated to be 264.73 ml higher in 3 or more levels compared to only 2 levels.

Finally, the analysis of blood reserves (sum over all visits) could proof no difference (floseal group 5 units, non-use 4 units). One sacrum fracture occurred as a SAE in the non-use group. Side effects showed no difference between both groups ( $P=0.742$ ).

ASS as a confounder showed a mean difference of 118,82 ml, which was also not significant ( $p=0.321$ ).

Outcome measures are subjected to subanalysis.

**Discussion:** This prospective RCT showed a difference between the groups of 94.3 ml. It was not possible to proof a significant difference in blood loss due to the intraoperative use of floseal. ASS showed no significant effect on blood loss. Epidurally applied floseal was a safe and efficacious hemostatic agent and can serve as a valuable part in the patient blood management of major spine surgeries.

## V 2

**Surgical treatment of recurrent lumbar spinal stenosis – analysis of results, complications and risk factors**\*T. Kratzsch<sup>1</sup>, O. L. Bieschke<sup>1</sup>, P. Vajkoczy<sup>1</sup>, S. Bayer<sup>1</sup><sup>1</sup>Charité Universitätsmedizin Berlin, Klinik für Neurochirurgie, Berlin, Germany

**Objective:** Microsurgical decompression (MD) of lumbar spinal stenosis (LSS) is a high frequent spinal surgery. However, recurrences can occur in the index segment. Here, we analyzed therapy options as well as spine imaging characteristics of patients with recurrent LSS.

**Methods:** A combined retrospective (preoperative analysis) and prospective (postoperative analysis) monocentric study. 899 patients after MD of LSS were analysed within a 5-year period. Recurrent disease of the index segment was defined as recurrent narrowing of the central spinal canal, lateral recess or neural

foramen, or new segmental instability, with new symptoms of claudication or sciatica after initial improvement of at least three months after initial decompression. Patient outcomes were assessed by VAS, SF36, ODI and RMDQ scores. Ethical approval was obtained (EA2/047/19).

**Results:** A cohort of 78 patients with surgically treated recurrent LSS was identified (24% female, 76% male, average age  $68 \pm 10$  years). A MD of the recurrent stenosis was performed in patients with new central spinal canal or recess stenosis without signs of instability (52 patients, 67%), and a spinal fusion was performed after occurrence of new instability in dynamic X-ray radiographs, progressive spondylolisthesis, new facet cysts or neuroforaminal stenosis (26 patients, 33%). Nine (17%) patients with a re-decompression had to undergo a subsequent fusion. Average time between the first decompression and the operation on the recurrent disease in the decompression and in the fusion group was  $3.7 \pm 5.7$  and  $1.7 \pm 1.1$  years, respectively. The most frequently re-operated segments were L4/5 and L3/4. In the instrumentation group, the rate of initial static spondylolisthesis was higher (23%) compared to the decompression only group (6%). In the fusion group, 24% of patients had a new unstable spondylolisthesis, 32% showed a progressive stable olisthesis and 44% had neuroforaminal stenosis, leading to instrumentation. Modic changes were similar in the decompression and in the fusion groups, whereas segments fused subsequently after a re-decompression had higher-grade Modic changes ( $p<0.05$ ). In this group, higher Pfirrmann-graded disc degenerations were observed ( $p<0.05$ ). Moreover, mean disc height was significantly decreased in segments with subsequent fusion after re-decompression ( $7.6 \text{ mm} \pm 1.7 \text{ mm}$  vs.  $8.7 \pm 1.8 \text{ mm}$ ,  $p<0.05$ ). In fused patients, facet joint effusions were less common.

**Results:** Surgery of recurrent disease of lumbar spinal canal stenosis consisted either of MD or additional fusion. The rate of spinal instrumentation after Redo-MD of the recurrent disease was 17%. We characterized typical imaging characteristics in all treatment groups. Risk factors for subsequent fusions were increased Modic changes, increased disk degenerations, and a lower disc height. This could be helpful in patient consultation and in surgical decision making regarding a Redo-MD with or without fusion.

## V 3

**Oblique cage insertion proves to be non-inferior compared to the anterior placement of semilunar insert-and-rotate cages in terms of restoring segmental lordosis**\*P. Truckenmüller<sup>1</sup>, M. Czabanka<sup>1</sup>, P. Vajkoczy<sup>1</sup><sup>1</sup>Charité- Universitätsmedizin Berlin, Neurochirurgie, Berlin, Germany

**Introduction:** For most effective restoration of the segmental lordosis (SL) in transforaminal lumbar interbody fusion (TLIF), it has repeatedly been proposed to place the interbody cage as anteriorly as possible, providing for a better load share in combination with dorsal compression. However, the existing data are controversial and the widely preferred insert-and-rotate technique with placement of a semilunar cage at the anterior vertebral rim entails a higher risk for endplate injury and intraoperative cage subsidence. We therefore tested the hypothesis, that oblique cage insertion across the intervertebral space allows for the same restoration of SL while causing less clinically relevant intraoperative cage subsidence.

**Method:** 50 patients who underwent single-level TLIF using the semilunar insert-and-rotate cage and 64 patients using an oblique cage were retrospectively identified, and preoperative and postoperative SL was analyzed. Further subgroup analysis was done according to the pelvic incidence (PI). The non-parametric Mann-Whitney U-test was performed and probability values below 0.05 were defined as significant.

**Results:** There was no significant difference in relordosation using a semilunar cage ( $5.13 \pm 0.81 \text{ SEM}$ ) or an oblique cage ( $5.04 \pm 0.69 \text{ SEM}$ ). Subgroup analysis of patients with a high PI over  $60^\circ$  revealed a trend for a better restoration of SL using the oblique cage after analysis of the Cobb angle ( $6.16 \pm 1.32 \text{ SEM}$  vs  $3.49 \pm 1.46 \text{ SEM}$ ;  $p=0.26$ ) while using the anterior vertebral body angle showed a significant difference ( $5.75 \pm 1.03 \text{ SEM}$  vs  $1.64 \pm 1.35$

SEM;  $p=0.03$ ). In our clinical praxis, 7.4 % (4 out of 54 patients) of the analyzed patients with a semilunar cage required a direct revision surgery using OLIF due to clinically relevant intraoperative cage subsidence after individual decision making, while no patients with an oblique cage underwent a direct revision.

**Discussion:** Previous studies showed that failure to correct SL after one-level TLIF surgery as well as failing to restore sufficient lumbar lordosis negatively affect the clinical outcome. However, right cage positioning in order to maintain SL still remains controversial. Our data demonstrate that TLIF using an oblique cage placed across the intervertebral space proves to be non-inferior in terms of relordosation. They further suggest a different effect on SL in subgroups according to the PI. While we experienced less clinically relevant intraoperative cage subsidence using the oblique cage, we therefore adapted our clinical praxis in TLIF surgical procedure.

**Table 1.** Comparison of preoperative and postoperative segmental lordosis: A oblique versus semilunar cage and B in subgroups according to the patients' PI. In each cell, the upper value demonstrates the Cobb angle and the lower one demonstrates the anterior vertebral body angle.

Fig. 1

A		Oblique Cage	Semilunar Cage	p-value
TLIF construct				
Mean SL preop ± SEM		16.66 ± 1.07 22.20 ± 2.42	17.49 ± 1.44 17.71 ± 2.46	
Mean SL postop ± SEM		21.70 ± 0.93 26.84 ± 2.32	22.62 ± 1.41 22.40 ± 2.38	
Δ SL postop–preop ± SEM		5.04 ± 0.69 4.63 ± 0.60	5.13 ± 0.81 4.69 ± 0.79	0.97 0.96
n patients		64	50	

B		Oblique Cage PI > 60°	Semilunar Cage PI > 60°	p-value	Oblique Cage PI 45–60°	Semilunar Cage PI 45–60°	p-value	Oblique Cage PI < 45°	Semilunar Cage PI < 45°	p-value
TLIF construct										
Mean PI ± SEM		68.39 ± 1.73 69.74 ± 1.71	68.39 ± 1.73 69.74 ± 1.71		52.15 ± 0.88 53.21 ± 0.79	52.15 ± 0.88 53.21 ± 0.79		37.79 ± 1.51 39.36 ± 0.95	37.79 ± 1.51 39.36 ± 0.95	
Mean SL preop ± SEM		19.27 ± 2.16 18.49 ± 3.55	22.09 ± 2.78 20.80 ± 3.76		16.22 ± 1.31 26.47 ± 4.02	15.78 ± 2.35 13.53 ± 3.82		12.15 ± 1.68 19.88 ± 5.79	15.20 ± 2.17 19.78 ± 5.14	
Mean SL postop ± SEM		25.44 ± 1.54 24.24 ± 3.24	25.58 ± 2.07 22.45 ± 3.69		20.41 ± 1.33 30.30 ± 3.95	22.37 ± 2.02 20.17 ± 3.77		16.95 ± 1.45 23.34 ± 5.30	20.14 ± 1.68 25.01 ± 4.98	
Δ SL postop–preop ± SEM		6.16 ± 1.32 5.75 ± 1.03	3.49 ± 1.46 1.64 ± 1.35	0.26 0.03	4.20 ± 0.98 3.83 ± 0.95	6.58 ± 1.30 6.64 ± 1.49	0.27 0.15	4.80 ± 1.10 4.32 ± 0.87	4.93 ± 1.43 5.23 ± 0.86	0.95 0.34
n patients		24	15		29	19		11	16	

#### V 4

##### 12 Months Results for a new CF/PEEK Pedicle-Cage TLIF system demonstrates high fusion rate

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**Introduction:** TLIF is a well-established and studied method to operatively treat degenerative changes in the lumbo-sacral spine<sup>1</sup>. Radiolucent cages and pedicle screws were developed to allow better postoperative assessment of bone and soft tissues. Even though the literature shows high fusion rates, good clinical outcome, and low implant-related complication rates using CF/PEEK composite cages for lumbar interbody fusion, there is still concern regarding delayed fusion rates with a radiolucent cages plus pedicle screw system<sup>2</sup>. The aim of our prospective, non-randomized, European multi-center study was to assess the overall fusion rate for a new CF/PEEK Pedicle system and a CF/PEEK Cage for a 1- or 2- level lumbar or lumbo-sacral spinal fusions with a TLIF for degenerative disc disease or spondylolisthesis grade I-II. This abstract presents the 12 months results of our study.

**Material & Methods:** From 01/ 2014 – 12/2018 we recruited 86 patients from 6 European spine centers. They all received a TLIF procedure using a CF/PEEK Pedicle system plus a CF/PEEK Cage. Our primary study endpoint was the overall fusion rate at 24 months using the 5° FXA method with flexion – extension radiographs as published by Schulze et al<sup>3</sup>. Clinical outcomes were assessed by using the VAS for back and leg pain as well as the Oswestry Low Back Pain Disability Questionnaire and the COMI. Data points were preoperatively, 3, 6 and 12 months

postoperatively. Implant related complications and adjacent segment disease were also evaluated as secondary study endpoints. For statistical analysis we used the McNemar test for proportions and the Wilcoxon for means.

**Results:** At 12 months, 78% (n=67) of the patients showed a complete data set including standing and flexion/extension radiographs. Out of the remaining 19 patients, 13 patients had an incomplete dataset (no flexion-extension radiographs), 4 patients (5%) underwent revision surgery and 2 patients withdraw their consent shortly after the initial surgery.

Average age was 58 years (range 20 – 80), 58% were female (n=50) and 42% (n=36) male patients, mean BMI 27.5 kg/m<sup>2</sup>(range 19 – 48). 32 % of the population smoked on a regular basis.

At 12 months 98.5% (n=66) presented with a fused TLIF (95% Confidence Interval: 91.96% – 99.96%). VAS for back pain decreased from 64 preoperatively to 25 at 12 months, leg pain from 63 to 23. Average preoperative ODI Score reduced from 50 and to 22 at 12 months, COMI from 7.8 to 3.1 points.

**Discussion:** These are the results at 12 months for a new vacuum plasma sprayed titanium coated Carbon/PEEK Pedicle System including a CF/PEEK Cage for a TLIF. We were able to demonstrate a high fusion rate of 98% with a low implant related complication rate of 5% and a good clinical outcome as measured with the ODI, VAS and the COMI. Our results are comparable to a conventional titanium Pedicle/Cage TLIF system with the advantage of increased visibility for fusion and MRI diagnostics.

<sup>1</sup> de Kunder SL et al.; Spine J. 2017 Nov;17(11):1712-1721.

<sup>2</sup> Ormond DR et al.; Clin Spine Surg. 2016 Aug;29(7):E371-5

<sup>3</sup> Schulze M et al.; J Biomech. 2011 Jun 3;44(9):1740-6

#### V 5

##### Long-Term Evaluation of PLIF after 20 Years

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**Objectives:** Degenerative spine disease may result in mechanical back pain, radicular pain, reduced mobility, and poor quality of life. Posterior lumbar interbody fusion (PLIF) of the affected levels is an established treatment option to stabilise painful motion segments, and to stabilise factual or expected instability. PLIF may provide indirect decompression of the neural elements, restore lordosis and correct deformity.

This study analyses the impact of different levels of posterior lumbar interbody fusion (PLIF) on the sagittal profile and the clinical outcome in long-term evaluation over 20 years in a cohort of 25 patients. It also evaluates the differences between fused segment levels (L4/L5, L4-S1, L5/S1) in radiographic and clinical parameters and the correlation between radiographic and clinical parameters as well as the rate of re-operations.

**Methods:** The sagittal profile was assessed preoperatively, with a follow-up at an average of 4 years (F-U4) and at a follow-up at an average of 20 years (F-U20) by standing lateral radiographs of the spine. These were performed in the routine examinations, and clinically by questionnaires in the form of the Oswestry Disability Index (ODI) and the Visual Analogue Scale (VAS) for back pain and data research for re-operations in our hospital register and the regional register. Statistical analysis was performed by ANOVA using the IBM SPSS 22.0 Software.

**Results:** Compared to the preoperative initial values (mean of value ODI = 45.62, VAS = 7.9) PLIF led to a decrease in disability and pain even after 20 years (ODI = 34.5, VAS = 4.5). The level of fusion has no significant impact clinically or radiographically (ODI PLIF at L4/L5 = 32.28, ODI PLIF from L4-S1 = 39.63 and ODI PLIF L5/S1 = 31.11). LL (lumbar lordosis) and LGSchwab (Lordosis Gap after Schwab) improved postoperatively (LL preoperatively = 54.8 vs LL F-U4 = 65.3, LGSchwab preoperatively = 4.3 vs LGSchwab at F-U4 = -6.2) and then returned to preoperative values after 20 years (LL at F-U20 = 55.7, LGSchwab at F-U20 = 3.4). Significant negative correlation exists between lumbar lordosis and the ODI ( $r = -0.469$ ); LGSchwab correlates significantly with the ODI Standing ( $r = 0.413$ ), but no other clinical parameter.

Until F-U20, 12% of patients (3 out of 25) patients underwent re-operation with extensions of the fusion due to Adjacent Segment Disease. There is a significant clinical difference at F-U20 between patients who did not undergo re-operation and those who die at F-U20 (ODI non-re-operated = 29.00 vs re-operated = 51.56).

**Discussion:** Compared to the preoperative values, PLIF significantly improves the clinical outcome even after 20 years, in spite of the regression of the radiographic parameter to the initial preoperative values between F-U4 and F-U20.

## V 6

### Sagittal Alignment, Adjacent Segment Disease and Pseudarthrosis after Short-segment Lumbar Fusion

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Adjacent segment disease (ASD) and pseudarthrosis represent well-known complications of lumbar spine surgery. To investigate whether differences in spinopelvic parameters, and especially spinopelvic alignment, could be associated with ASD or pseudarthrosis after short-segment lumbar fusion.

**Methods:** Retrospective study of patients offered mono- or bisegmental transforaminal lumbar interbody fusion (TLIF) with polyetheretherketone (PEEK) or titanium cages, due to degenerative lumbar spine disease. Cases with spondylolysis, congenital vertebral anomalies, infections, fractures and scoliosis greater than 20° were excluded. Patients were followed averagely for 50 months (range, 36–84 months), and the presence of fusion, pseudarthrosis or ASD was documented in their files after clinical and radiological evaluation. If pseudarthrosis was suspected each patient was examined by thin-cut CT.

**Results:** 419 patients (252 women and 167 men; mean age, 71 ± 11 years), 32 (7.6%) presented pseudarthrosis (Nonunion group), 29 (6.9%) developed symptomatic ASD (ASD group), and 358 patients (85.5%) showed evidence of uncomplicated fusion (Control group). Standard spinopelvic parameters, namely pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), L1-S1 lumbar lordosis (LL), L4-S1 lordosis (L4S1), and the lumbo-pelvic mismatch (PI-LL; PI minus LL modifier is considered an assessment tool for sagittal alignment) were measured in all patients before and after surgery.

All studied parameters changed significantly after surgery both in the Control and ASD group, while in the Nonunion group only LL and PI-LL changed significantly (PI-LL increased from 10±11 to 14±10 degrees,  $p=0.008$ ). Patients in the Nonunion group presented greater SS before and after surgery, greater PI-LL after surgery, and higher PI, while ASD patients presented greater absolute mean  $\Delta$ PT value. Age, size and type of cage were not related to fusion, nonunion or ASD.

**Conclusion:** Greater SS, greater PI, and a PI-LL mismatch greater than 10 degrees are associated with failed bony fusion, while ASD is related to a greater difference between the preoperative and postoperative values of PT. Neither the type nor size of cage seem to have a significant impact on either solid bony fusion, nonunion, or ASD rates. Thus we recommend on the study of patients' sagittal alignment in the preoperative setting even when treating patients with short-segment lumbar interbody fusion.

## V 7

### Correlation analysis of CT- and DXA- measured BMD in patients with lumbar spine instrumentation

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**Introduction:** Reduced bone mineral density (BMD) is a well-known risk factor for postoperative mechanical complications in spinal instrumentation of the elderly. In addition to dual x-ray absorptiometry (DXA) scans considered to be the gold standard for BMD screening, the use of computed tomography (CT) increases. The aim of this study was to investigate a correlation of BMD measured preoperatively using CT- and DXA-scans in patients planned for lumbar spinal fusion surgery.

**Material & Methods:** All patients scheduled for lumbar spinal instrumentation who were screened by both preoperative lumbar CT- as well as DXA scans between 2009 and 2019 were retrospectively included. CT-BMD was measured using the "Schreiber-technique", with a recommended time span between CT and DXA below 12 months. Patients with cervical or thoracic surgery as well as tumor-associated spine disease were excluded from the study.

**Results:** 64 patients (51 women, 13 men) with a mean age of 65 years were analyzed. The mean BMD was  $95.2 \pm 32.5$  Hounsfield units (HU) on CT, while the BMD measured by DXA revealed to be  $1.0 \pm 0.3$  and  $0.6 \pm 0.2$  g/cm<sup>2</sup> for the lumbar spine and the femoral neck, respectively. The Pearson correlation analysis demonstrated a significant correlation between CT-HU units and DXA scans of the femoral neck ( $R^2 = 0.41$ ,  $p < 0.001$ ), while no significant correlation between DXA scans of the lumbar spine and CT scans was shown ( $p > 0.05$ ). The correlation between DXA scans of the femoral neck and lumbar spine was also poor ( $p > 0.05$ ).

**Discussion:** DXA scans particularly of the lumbar spine may not assess bone mineral density effectively. Due to various influential factors and local variations BMD measurement of the lumbar spine by the means of CT may be a more reliable tool. Further studies are necessary to evaluate the assessment of osteoporosis by preoperatively routinely available CT.

## V 8

### Individualized computersimulation of the lumbar spine in patients with degenerative spondylolisthesis

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**Introduction:** CT, MRI and X-rays are currently used in the decision for a suitable surgical procedure in spinal surgery. However the dynamically complex behavior of the spine is only insufficiently taken into account in these static images. Dynamic investigation methods that incorporate functional parameters could bring decisive improvements here. Computer simulation models could fill this diagnostic gap and help to improve therapy decisions from a biomechanical point of view [1].

**Methods:** A biomechanical computer simulation model that can be adapted to individual patient spines was developed (multi-body simulation). Using the example of degenerative spondylolisthesis, the simulation was used to compare the destabilizing effects of interlaminar fenestration (ILF) with those of a laminectomy (LAM).

Retrospectively, 9 patients with degenerative spinal stenosis and accompanying spondylolisthesis were identified, who were treated in our clinic from 01/01/2017 to 07/30/2018. Inclusion criteria were monosegmental spinal stenoses of the lumbar spine with ventral displacement of the vertebral bodies. Preoperative CT and X-ray functional images had to be available. Instability, previous operations or fractures were excluded. The mean patient age was 69.7 years (m: f = 4: 5).

The model was adapted to the individual geometry using the CTs. An inclination movement was then simulated for each spine so that the end positions determined from the X-ray function images were reached (Fig. 1).

The ligaments that would also be surgically removed in an ILF or a LAM were then removed from each individual model. Again an inclination movement for ILF and LAM was simulated and the changes regarding an increasing ventral displacement or an angle change were calculated.

**Results:** With regard to the percentage change in the ventrodorsal distances (ventral sliding) of the vertebral bodies, there was a significant increase after LAM compared to an ILF. For example, after ILF there was 2% more ventral gliding in LWK 3, whereas it was 6.5% in LAM (Fig. 2)

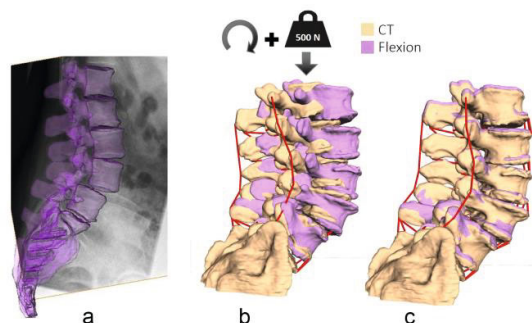
With regard to the angles, the ILF showed deviations of: 1% – 10.5%. In contrast, at LAM from 3.6% – 15.6%.

**Discussion:** On average these results show a destabilizing effect of the LAM more than twice as high than it would occur after ILF. This corresponds to the clinical observation of the potentially destabilizing LAM (today only carried out with accompanying spondylolysis) and could now also be quantitatively reproduced in the presented computer simulation model.

This offers the chance to be able to predict in the future which patients would and would not be likely to benefit from an additional surgical step, such as spinal fusion.

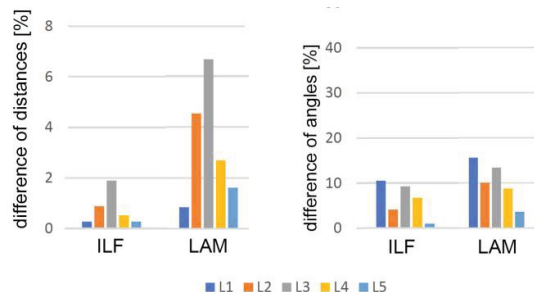
**References:** [1] Dreischarf, M., Shirazi-Adl, A., Arjmand, N., Rohmann, A. and Schmidt, H. Estimation of loads on human lumbar spine: A review of in vivo and computational model studies. *J Biomech*, 49, 6 (Apr 11 2016), 833-845.

**Fig. 1**



**Fig. 1:** a: matching of the vertebra to the flexion posture derived from functional X-ray imaging. b: simulation model with neutral posture from CT imaging and target posture from step a. c: final result after simulating the flexion movement.

**Fig. 2**



**Fig. 2:** left: mean changes of the positions of vertebrae from neutral to inclination in cases of ILF and LAM in percent  
right: mean changes of the angles of the vertebrae from neutral to inclination in cases of ILF and LAM in percent.

## V 9

### Platelet Rich Fibrin Augmentation Of Persistent Deep Surgical Site Infections after Instrumented Spinal Surgery: Initial Single Center Experience

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**Introduction:** Deep surgical site infection after instrumented spinal surgery is a common (incidence: 12%) and cost intensive complication. Yet, universally accepted management protocols are lacking. Extensive surgical debridement and targeted antibiotic treatment is frequently insufficient and associated with multiple revision surgeries. Extended tissue destruction often precludes primary wound-closure. Costly and complex secondary wound-closure options, requiring months of treatment, are often needed.

Platelet rich fibrin (PRF) is an autologous low cost biomaterial, easily prepared in the operating theater by an 8min angulated centrifugation cycle of the patients own blood, without any additional chemical additives. It is comprised of a fibrin matrix with high concentrations of slowly released platelet derived growth-factors. PRF has shown remarkable cicatrization and

wound healing properties in various regenerative medicine applications.

In this study we explored the augmentation of tissue deficits with platelet rich fibrin in patients with deep surgical site infection after instrumented fusion.

**Methods:** A total of 12 patients who presented with a deep surgical site infection after instrumented spinal surgery were included. After extended resection of the necrotic tissue and identification of the involved pathogens, targeted intravenous antibiotics was initiated. Despite primary wound closure and suction drainage for about 3 days wound-dehiscence and secretion of fluids persisted in all cases. We performed a second surgical debridement, and the remaining post-infectious tissue deficits, were augmented with solid Platelet Rich Fibrin membranes (s-PRF) obtained from the centrifugation of 50 ml of the patients blood. The main cavitation and the surrounding tissues were further augmented with 20 ml of injectable PRF (iPRF). Primary wound closure was achieved in all patients. We used no closed suction-drains and no local antibiotics. The intravenous targeted antibiotic regimen was administered for 2 weeks postoperatively, followed by two weeks of oral administration. Regular wound inspections and laboratory follow ups were performed every two weeks for 3 months.

**Results:** *Staphylococcus aureus* was the identified pathogen in all cases. All patients showed positive blood culture results for the same pathogen. Infections resolved in all patients. Primary wound healing was found in all patients with no recurrence of infection during the follow up period. Instrumentation was not removed and showed no signs of failure in the clinical and radiological follow ups.

**Discussion:** Post-infectious tissue defects can be augmented and wound healing may be supported with platelet rich fibrin, an autologous low-cost biomaterial easily prepared in the operating theater.

## V 10

### Surgical site infections after posterior (thoraco-)lumbar instrumentation: Outcome in 172 patients

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**Objective:** Surgical site infections (SSI) in patients with posterior spinal instrumentation pose a challenge to patients, treating physicians and the health care system. Literature on the most appropriate treatment is scarce and data on the need for removal of implants are contradictory. Thus, we retrospectively analysed the management and clinical outcome of such patients at our institution.

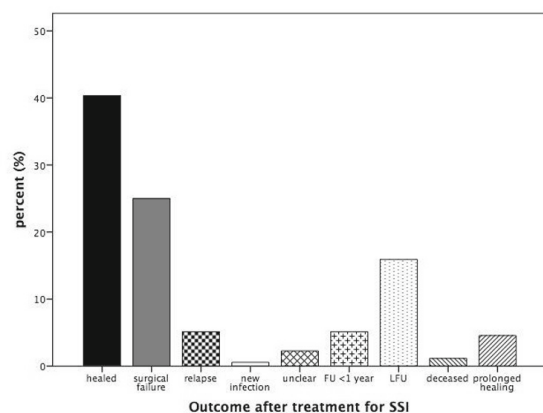
**Methods:** Our in-house databases of prospectively documented surgeries and infectious diseases were searched for eligible patients (01/2008-06/2018). Patient files were reviewed for age, gender, BMI, smoking status, medical history, details of surgery (duration, local antibiotics, debridement and implant retention (DAIR), partial (-cage) or complete (+cage) implant removal/exchange), causative pathogens, antimicrobial treatment, and outcome. Infection outcome was assessed in patients with  $\geq 1$  year follow-up (FU) (healed=no revision & no suspected signs of infection; surgical failure (sf)=non-septic revision; relapse=readmission for septic revision with same pathogen; new infection=new pathogen on septic revision; cure=healed & sf). Patient-reported outcome (PRO) was documented with the Core Outcome Measures Index (COMI) assessing pain on a 10-point scale, function, well-being, quality of life, disability.

**Results:** 172 patients (31.8% male; 65.3 $\pm$ 12.8y; BMI 29.3 $\pm$ 5.6 kg.m-2, 23.0% smokers) underwent 214 revisions for 178 SSI.

Median time between index and revision surgery was 23d (7d – 11y). In 65% (139/214) deep subfascial infection was macroscopically diagnosed intraoperatively. The most commonly isolated pathogens were *Staphylococcus epidermidis* (n=80, 37.4%) and *Staphylococcus aureus* (n=56, 26.2%); n=28 polymicrobial (13.1%). DAIR was done in 136/214 (63.6%) surgeries, partial removal/exchange of loose implants in 61/214 (28.5%), and complete removal/exchange in 14/214 (28.5%); missing n=3 (1.4%). Persistent infection required multiple revisions (up to 4) in 29/178 SSI (16.3%). Surgery was followed by intravenous and oral antimicrobial treatment for 10–12 weeks. In the 136 SSI (76.4%) with  $\geq 1$ -y FU, infection was cured in 113 (83.1%); relapse occurred in 9 cases (relapse rate: 6.6%). Two patients (1.4%) died due to uncontrolled infection. COMI decreased significantly ( $p < 0.001$ ) from  $8.2 \pm 1.5$  before treatment to  $4.8 \pm 2.9$  at the 1y-FU. A significant reduction in pain was noted within the first year (backpain:  $6.7 \pm 2.3$  vs.  $3.7 \pm 2.8$ , legpain:  $5.8 \pm 3.3$  vs.  $3.1 \pm 2.8$ ,  $p < 0.001$ ). 93.3% of patients with a completed COMI (n=112/120) were satisfied with the overall treatment received.

**Conclusion:** In most cases, patients with SSI after posterior spinal instrumentation can be successfully treated with optimal surgical and antibiotic treatment. Implants could be retained in the majority of cases. Multiple revisions may be necessary in selected cases. PRO are satisfactory. These results may serve for future establishment of treatment algorithms and patient information.

**Fig. 1**



## V 11

### Does antibiotics therapy prevent de novo screw loosening after initial aseptic screw loosening with low-virulent microorganism colonization? – A prospective observational study

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**Introduction:** Screw loosening after spondylodesis represents a common postoperative complication after spine surgery with heavy burden on both patients and healthcare stakeholders. Low-virulent microorganism colonization exposed by sonication was identified as a possible cause for symptomatic implant case. However, the role of antibiotics administration for de novo screw loosening prevention remains unclear. The aim of our study was to determine whether antibiotics administration after positive sonication prevents de novo screw loosening.

**Material/Methods:** After positive ethics vote (EA2/047/19) all patients from January 2015 – July 2018 were identified undergoing revision surgery and examination of explanted screws for microorganism colonization with sonication. All identified patients were invited for clinical and radiographic follow-up.

Screw loosening was evaluated in CT-scans carried out at least 12 months after revision surgery. Subdivision into three groups was conducted: Group 1a included all patients with positive sonication results and postoperative antibiotics treatment, Group 1b involved all patients with positive sonication results without postoperative antibiotics treatment and Group 2 served as reference cohort containing all patients with negative sonication results.

**Results:** 79 patients (51 female, mean age 65.12 years) were identified. 25 patients agreed to participate in follow-up (31.6%). Eligible CT-scan for screw loosening evaluation was available in 42 patients (51.2%). This patient population was segregated into the three groups (Group 1a – n=5, 12%, Group 1b – n=8, 19% and Group 2 – n=29, 69%). In 10 out of 13 patients with positive sonication (Group 1a + Group 1b) de novo screw loosening occurred (76.9%) whereas antibiotics administration had no influence on screw loosening rates (4 out of 5 patients in Group 1a and 6 out of 8 patients in Group 1b). In the reference Group 2 in 11 out of 29 patients de novo screw loosening was identified (37.9%).

**Discussion:** Low-virulent microorganism colonization plays an important role in the incidence of screw loosening. No benefit for antibiotics administration in patients with positive sonication could be depicted. New ways of biofilm formation prevention have to be established.

## V 12

### Vertebral osteomyelitis in patients with *Staphylococcus aureus* bloodstream infection: evaluation of risk factors for failure

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**Objectives:** *Staphylococcus aureus* is the most common cause of hematogenous pyogenic vertebral osteomyelitis (VO) in adults. Studies indicate that *S. aureus* VO results in a particularly poor outcome. We aimed to investigate risk factors for treatment failure in patients with *Staphylococcus aureus* bloodstream infection (SAB) associated with VO.

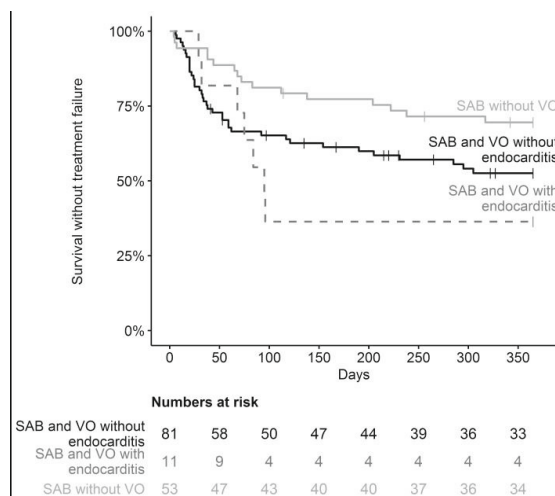
**Methods:** We conducted a post hoc-analysis of data from a German bi-center prospective SAB cohort study (period 2006–2014). Patients were followed-up for one year. Primary outcome was treatment failure defined as relapse and/or death within one year. We performed a multivariable analysis and compared outcome of patients with VO with and without endocarditis and those with non-vertebral osteomyelitis.

**Results:** A total of 1069 patients with SAB were analyzed, with 92 patients presenting with VO. MRSA rate was 13%. Median antimicrobial treatment duration in hospital was 34 days (IQR 21–53) with all patients receiving combination therapy (cell wall-active agent plus predominantly rifampicin or fosfomycin). In addition to antibiotic treatment, surgery was performed in 60/92 (65%) patients. 44/92 patients (48%) failed (death, n=42; relapse, n=2). Multivariable analysis revealed higher age (HR 1.04 [per year], 95% CI 1.01 – 1.07), Charlson comorbidity index (HR 1.20, 95% CI 1.06 – 1.36), the presence of a neurologic deficit (HR 2.53,

95% CI 1.15 – 5.53) and abscess (HR 3.35, 95% CI 1.39 – 8.04) as independent risk factors for treatment failure within one year whereas surgery was associated with a favourable outcome (HR of 0.45 (95% CI 0.20–0.997). Patients with VO and endocarditis showed the highest rate of treatment failure (see figure).

**Conclusion:** SAB patients with VO exhibit a high treatment failure rate. Red flags are older age, comorbidities, secondary foci or neurologic deficits. Whether these patients benefit from intensified treatment (e.g. earlier radical surgery, prolongation of antibiotic treatment) should be investigated in further studies.

**Fig. 1**



### V 13

#### What is the impact of the simultaneous presence of endocarditis in patients with spondylodiscitis? – a analysis on 297 patients of the years 2013–2020

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Spondylodiscitis has an increasing incidence, currently 5–7:100,000. It often affects multimorbid patients. The simultaneous presence of endocarditis in already diagnosed spondylodiscitis is reported in the literature as approx. 12–33% (Mylona et al. 2009, Behmanesh et al. 2019). The aim of this study was to investigate the influence of the simultaneous presence of spondylodiscitis and endocarditis (SE) on the course of the disease compared to the patient group with isolated spondylodiscitis (S).

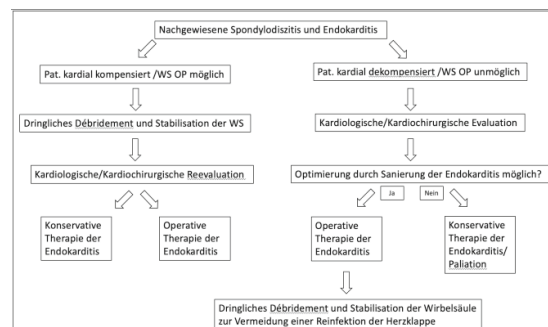
In our hospital we have identified all patients who were treated for spondylodiscitis in the period 6/2013–5/2020. The data was collected retrospectively using the digital patient files. This was followed by statistical evaluation and a matched pair analysis using the Propensity Score (SPSS, Vers. 25).

During the period, 297 patients were included. Of these, 32 patients (10.8%) showed a simultaneous endocarditis. There were no significant differences in gender (male S=64.2% vs. SE=75%), age (S=65.7±14.3 vs. SE=69.9 ± 9.4 years) or number of infected segments (S=1.49±1 vs. SE=1.66±1.4). The number of secondary diagnoses did not differ (S=2.2±1.7 vs. SE=2.4±1.9). 221 patients were examined using echocardiography. Endocarditis was diagnosed in 32 cases. Mortality in the SE group was 25% (n=8), twice as high as in the S group with 12% (n=33). In the collective matched according to age, gender, BMI and secondary diagnosis, 31 couples were identified. A significantly longer stay in the SE group (S=20.25 vs. SE=35.67 days, p=0.02) and a longer i.v. Antibiotic therapy (S=23 vs. SE=40 days, p=0.003) was found. There was also a delay in the start of surgical therapy (S=3.7 vs.

SE=8.3 days, p=0.031). Mortality did not differ significantly in the propensity score analysis.

We can show that our collective corresponds to the previously published collectives in many ways. We believe that the cohort is too small to ensure reach any significance regarding the mortality rate despite doubling in the SE group. In comparison to the literature, we were able to show for the first time that the simultaneous presence of endocarditis in spondylodiscitis does not only lead to a longer i.v. antibiotic therapy and inpatient stay, but that it takes twice as long for these patients to be treated surgically. We attribute this to a difficult decision-making process. To meet this interdisciplinary challenge, we have established the diagram shown in Figure 1 to avoid delaying therapy in critically ill patients.

**Fig. 1**



### V 14

#### Minimally invasive posterior instrumentation in elderly patients with thoracolumbar pyogenic spondylodiscitis: A prospective multicenter observational trial

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**Introduction:** Thoracolumbar spondylodiscitis primarily affects elderly and multimorbid patients. Consecutive destruction of the disc and vertebral body can lead to spinal instability, therapy-refractory pain, and immobilization. A minimally invasive posterior instrumentation with a percutaneous/transmuscular pedicle screw and rod system might be a safe and effective surgical option to restore spinal stability, and to allow for fast pain reduction and ambulation.

**Material/Method:** Prospective multicenter observational trial of patients undergoing a navigation-guided and 3D-imaging controlled minimally invasive posterior instrumentation for thoracolumbar spondylodiscitis. The primary outcome parameter was the change of the Oswestry Disability Index (ODI) at 6 months after surgery, secondary outcome measures were change of local pain intensity (Visual Analogue Scale) and quality of life (EQ-5D-3L) at 6 months, as well as intraoperative details, time to ambulation, recurrence of the infection in conjunction with standard antibiotic treatment, complications, and reoperations.

**Results:** 38 patients were enrolled in the study of which 6 patients with an incomplete dataset, 2 patient who withdrew the study consent and 1 patient, that died 5 months after surgery, had to be excluded, thus leaving 29 patients for the final analysis. These patients (male: n=24) who underwent surgery between 4/2016 and 9/2019 (median follow-up: 6 month) had a median age of 73 years and a median Charlson Comorbidity Index of 2. The median duration of surgery was 150 min., and the median blood loss was 100 ml. The ODI, VAS and EQ-5D-L were changed from 70%, 7.0 and 73.3 preoperatively to 20% ( $p<0.001$  vs. preop.), 3.0 ( $p<0.001$  vs. preop.) and 91 ( $p<0.001$  vs. preop.) at 6 months. The median time to ambulation was 1 day. There was one recurrent infection that was treated conservatively. Complications – none of them were severe/life-threatening – occurred in five patients, reoperations had to be carried out in three patients due to screw loosening with kyphosis and instability (n=1) and due to impaired wound healing (n=2).

**Discussion:** A minimally invasive posterior instrumentation in elderly patients with a thoracolumbar spondylodiscitis allows for fast mobilization and significant improvement of disability, pain and quality of life at 6 months after surgery. Furthermore, the technique seems to be safe and, in conjunction with standard antibiotic treatment, cure of the infection is most probable.

## V 15

### Surgical nuances and construct patterns influence construct stiffness in C1-2 stabilizations – A biomechanical study of C1-2 gapping and advanced C1-2 fixation

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**Introduction:** Stabilization of C1-2 using a Harms-Goel construct with 3.5 mm Ti rods has been established as standard of reference (SOR). To avoid extending instrumentation to the occiput, a fusion restricted to C1-2 and reduction of a craniocervical deformity can indicate increased construct stiffness at C1-2. In the treatment of craniocervical deformities surgical reduction of C1-2 can result in C1-2 joint gapping. This can stress-shield the C1-2 facets and cause direct increased loads to the posterior instrumentation.

The authors sought to study the biomechanical consequences of C1-2 gapping on construct stiffness using different instrumentations, including a novel 6-screw/3-rod (6S3R) construct, and to compare the results to the standard of reference (SOR).

**Methods:** The range of motion (ROM) of instrumented C1-2 polyamide models was analyzed in a six-degree-of-freedom spine tester. The models were loaded with pure moments (2.0 Nm) in axial rotation (AR), flexion-extension (FE), and lateral bending (LB). Intersegmental motion was measured using an ultrasound-based motion analysis system. Comparisons of C1-2 construct stiffness among the constructs included variations in rod diameter (3.5 mm vs. 4.0 mm), rod material (Ti. vs. CoCr), and a crosslink (CLX). The 6S3R-construct included an additional 3.5 mm Ti rod connected to C1 and C2 laminar screws. Construct stiffness was tested with C1-2 facets in contact (Contact-Group) and in a 2 mm distracted position (Gapping-Group).

The ROM (°) was recorded and reported as a percentage of ROM (%ROM) normalized to the SOR. A difference >30% between the SOR and the %ROM among the constructs was defined as significant.

**Fig.1** explains the clinical scenarios tested and shows examples of C1-2 gapping cases in a patient with a) basilar invagination b) basilar impression from rheumatoid arthritis c) unintended distraction of the C1-2 facets after fracture reduction d) Bone on bone contact of C1-2 facets or e) a lateral column buttress between C1-2.

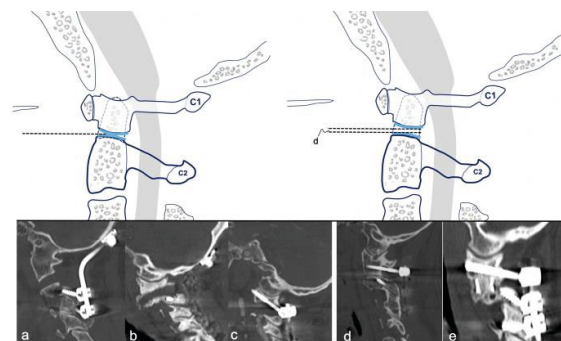
**Results:** Among all constructs tested, an increase in construct stiffness up to 50% was achieved with the addition of a CLX and particularly with a 6S3R-construct. These differences were varied

and showed the greatest effect for the CLX in AR-testing and for the 6S3R-construct in FE- and AR-testing.

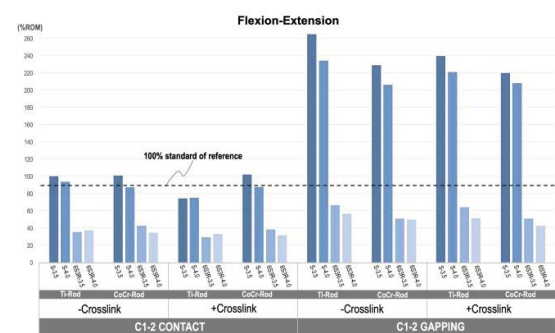
Among all constructs, C1-2 gapping resulted in a significant loss of construct stiffness. A protective effect was shown for the CLX, particularly using a 6S3R-construct in AR- and FE-testing. The selection of rod diameter (3.5 mm vs. 4.0 mm) and rod material (Ti vs. CoCr) did show a constant trend but did not yield significance.

**Conclusion:** This study is the first to show the loss of construct stiffness at C1-2 with gapping and increased restoration of stability using CLX and 6S3R-constructs. In the correction of a craniocervical deformity, nuances in the surgical technique and advanced instrumentation may positively impact construct stability.

**Fig. 1**



**Fig. 2**



## V 16

### The role of the transversal ligament on the occipito-atlantoaxial complex – strain and stresses at C1/2 inclination limits

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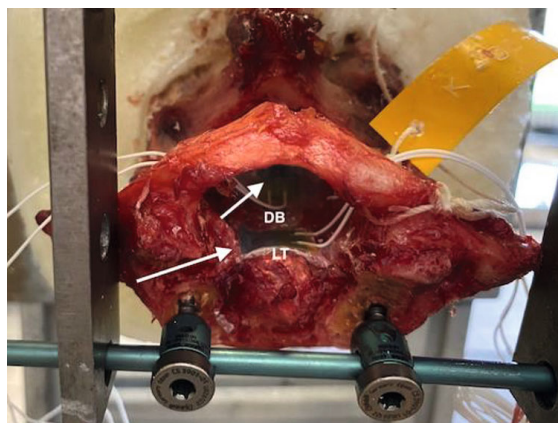
**Background:** Biomechanical functionality as well as trauma mechanisms of the atlantoaxial complex are still an issue of controversy. The stability of the atlantoaxial functional union is not ensured by the fovea dentis or the lateral facet joints of C0, C1 and C2 merely, mostly dislocation is prevented by the ligaments. The transversal ligament is the strongest stabilizer and limits inclination as well as extension at C1/2-joint. The aim of the presenting study is to analyze the strain of the transversal ligament and of the base of the odontoid process during C1/2 inclination.

**Material & Methods:** In this biomechanical study 5 cadaveric HWS (C1-C3) with a mean age of 72 at death and bone mineral density measuring for 555.3 HU on average were used. To analyze the strain and stresses strain gauges (4-wire-350 Ohm; Fa. Vishay) were fixed on the transversal ligament and the base of C2. A custom biomechanical setup was used to test the samples with a constant valley load. Each specimen was tested at C1/2 inclination (+10 mm/+15 mm) and strain of the transversal ligament and the dens base (µm/m) were measured.

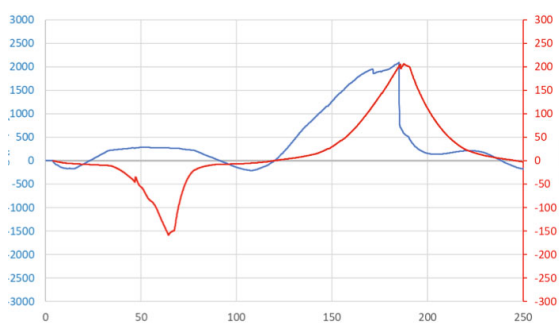
**Results:** Mean strain of the transversal ligament at + 10 mm-C1/C2 inclination was 2145.8  $\mu\text{m}/\text{m}$  (min. 1924.5  $\mu\text{m}/\text{m}$ ; max. 2515.2  $\mu\text{m}/\text{m}$ ; SD 273.5) by a mean valley load of 146.78 N (min. 99.8 N; max. 201.3 N; SD 41.04). Corresponding to the transversal ligament the mean distension of the dens base was 177.2  $\mu\text{m}/\text{m}$  (min. 158.6  $\mu\text{m}/\text{m}$ ; max. 206.8  $\mu\text{m}/\text{m}$ ). In 4 out of 5 we have observed a rupture of the transversal ligament at +15 mm-C1/C2 inclination, the power of resistance accounts for 174.65 N on average (min. 99.8 N; 249.2 N; SD 64.7) by a mean tension of 2102.9  $\mu\text{m}/\text{m}$  (min. 1953.5  $\mu\text{m}/\text{m}$ ; max. 2272.3  $\mu\text{m}/\text{m}$ ; SD 189.7). In one specimen (155 HU), the dens base fractured before the transversal ligament ruptured and no tension could be measured at the transversal ligament during movement afterwards.

**Conclusion:** Depending on the bone density C1/C2 inclination could create high tension on the transversal ligament. The transversal ligament allows a mean tension of 2102.9  $\mu\text{m}/\text{m}$  before loss of resistance. In case of a fracture of the dens base the transversal ligament might have no influence on the C1/2 stability.

**Fig. 1**



**Fig. 2**



## V 17

### Comparative biomechanical investigation of pedicle screw-rod instrumentation made of carbon reinforced PEEK and titanium in relation to the loosening rate in an osteoporotic spine model

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**Background:** Implants made of carbon-reinforced PEEK have been developed to stabilize tumors or metastases at the spinal column that are prone to fracture. These implants have a lower stiffness than titanium or cobalt-chrome implants. In osteoporotic bone, this property can be an advantage in terms of implant

anchorage or loosening. The aim of this biomechanical cadaver study is to compare the effects of pedicle screw instrumentation made of carbon reinforced PEEK with the established titanium pedicle screw instrumentation and to investigate differences in the loosening rate and the formation of cavities on the implant.

**Material/Method:** A total of 10 human lumbar cadaver spinal columns (LWK1-LWK5) were divided into 2 groups: (A) monosegmental dorsal pedicle screws/rod instrumentation of LWK3-LWK4 with titanium-based pedicle screws; (B) monosegmental dorsal pedicle screws/rod instrumentation of LWK3-LWK4 with carbon-reinforced PEEK pedicle screws. After CT-graphic position control of the pedicle screws, cyclic axial testing was performed at a frequency of 3 Hz with 950N and combined minimum load of 100N for a total of 100,000 cycles in our spine test rig. This was followed by a CT-graphic examination with regard to the loosening of the pedicle screws. For this purpose, the digital measurement of cavities around the pedicle screws was performed at 3 defined measuring points. Finally, the maximum axial force required to achieve a Lost of Resistance (80% Fmax) was examined.

**Results** The mean T-score was  $-3.77 \pm 1.28$  (min.: -1.69, max.: -5.98) with an equal distribution in both groups (mean age of the cadaver spine 79.8 years (min.: 70, max.: 95)). All pedicle screws showed a correct intrapedicular position. Neither the spinal columns from the group of titanium-based pedicle screws nor the spinal columns instrumented with carbon reinforced PEEK showed a significant difference compared to the maximum axial force application (group A: 2835 N, group B: 3006 N,  $p = 0.595$ ) or the maximum compression (group A: 11.67 mm; group B: 15.15 mm;  $p = 0.174$ ). All spines reached the full cyclic load of 100,000 cycles. A significant difference in the formation of cavities around the pedicle screws could be shown in both groups ( $p = 0.007$ ). The cavity around the pedicle screw was significantly smaller in group B than in group A, especially around the tip of the pedicle screw ( $p < 0.001$ ). Macroscopic loosening of the pedicle screws with simultaneous implant failure was not observed in either group.

**Conclusion:** In the osteoporotic spine model, the use of carbon-reinforced PEEK implants seems to be advantageous in terms of microscopic screw loosening compared to titanium implants. Therefore, the use of carbon-reinforced PEEK implants could result in a lower pedicle screw loosening rate compared to titanium implants in osteoporotic bone.

**Fig. 1**

Table 1

Demographic and specific data and overview of the grade of osteoporosis and BMD.

Specimen	CFR/PEEK pedicle screws	age (years)	gender	grade of osteoporosis (T-score)	BMD (mg Ca-HA/ml)	failure load (N)	Count of completed cycles (950 N/cycle)
#1	X	77	f	-2.99	95.5	3637.491	100000
#2	X	71	m	-5.98	16.2	2976.394	100000
#3	X	81	m	-4.36	59.1	2191.713	100000
#4		95	f	-4.82	46.9	2281.000	100000
#5		70	m	-2.41	110.9	3876.529	100000
#6		79	f	-3.38	85.1	2378.424	100000
#7		88	f	-1.69	130	4470.196	100000
#8	X	74	f	-4.93	44.1	3039.364	100000
#9		79	f	-3.49	82.3	2025.699	100000
#10	X	84	f	-3.68	77.3	1474.89	100000
Total (average)	-	79.8 (SD 7.70)	-	-3.77 (SD 1.28)	74.74 (SD 33.91)	2835.17 (SD 936.81)	-
group a (average)	-	82.2 (SD 9.58)	-	-3.16 (SD 1.19)	91.04 (SD 31.51)	3006.37 (SD 1093.41)	-
group b (average)	-	77.4 (SD 5.22)	-	-4.39 (SD 1.15)	58.44 (SD 30.50)	2663.97 (SD 840.12)	-

**Fig. 2**

Table 2

Analysis of the cavities around the pedicle screws at 3 specified measurement points in mm.

Significant parameters are marked bold.

	CFR/PEEK pedicle screws	titanium pedicle screws	p-value
Point 1	1.09 (SD 1.07)	2.47 (SD 0.99)	<b>&lt;0.001</b>
Point 2	1.17 (SD 0.95)	1.48 (SD 0.89)	0.286
Point 3	0.76 (SD 0.76)	1.19 (SD 0.66)	0.183
Total Cavity	3.01 (SD 2.22)	5.14 (SD 2.47)	<b>0.007</b>

## V 18

**Can screw loosening be predicted by measuring the insertion torque? – an in vitro study**\*J. U. Jansen<sup>1</sup>, L. Zengerle<sup>1</sup>, C. Hackenbroch<sup>2</sup>, Y. Tao<sup>1</sup>,H. J. Wilke<sup>1</sup><sup>1</sup>Universitätsklinikum Ulm, Institut für Unfallchirurgische Forschung und Biomechanik, Ulm, Germany<sup>2</sup>Bundeswehrkrankenhaus Ulm, Klinik für diagnostische und interventionelle Radiologie und Neuroradiologie, Ulm, Germany

**Introduction** Screw loosening has been reported with rates up to 60 % for osteoporotic and less than 15 % for non-osteoporotic patients [1,2]. Most of the reports perform pullout tests, but screw loosening is most often the outcome of a "windshield-wiper effect", starting with failure of the screw-bone interface as a result of bending [3]. Hence, it would be advantageous to estimate the risk of screw-bone interface failure in order to decide where screw augmentation should be performed or if reducing distraction forces applied during surgery is required. Could the risk be directly estimated without radiation during screw insertion intra-operatively? The purpose of this in vitro experiment was to correlate the screw insertion torque with a bending force necessary to create screw loosening in non-osteoporotic vertebrae.

**Material/Method** In total, 100 pedicle screws were implanted into both left and right pedicles of 50 single vertebrae (14 donors, T9-L4, mean age 41±8) with a median bone mineral density (BMD) of 145 (120–299) mgCaHA/cm<sup>3</sup> which was measured with QCT. After pre-drilling (2.5x20), the appropriate screw (5.5x40, 5.5x45, 6.5x40, 6.5x45, or 6.5x50) was implanted into the pedicle while measuring the insertion torque. Both endplates were embedded in PMMA and fixed in a material testing machine. As seen in Fig. 1, a bending force was applied on the screw head until reaching a displacement of 1 mm (5 N pre-load, 10 mm/min). Afterwards, a univariate and multiple mixed linear model was calculated (SPSS; significant level 0.05).

**Results** The bending force increased linear with the insertion torque (multiple;  $p=0.0002$ ) (Fig. 1). The length and the diameter of the screw as well as the vertebral level had a significant impact on the bending force in the univariate model ( $p<0.0001$ ) but not in the multiple one. BMD did not affect the bending force (univariate;  $p=0.2483$ ). The screw diameter showed a slight trend for the multiple model ( $p=0.0584$ ).

**Discussion** The correlation of insertion torque and the bending force suggests an alternative prediction metric for screw loosening which could improve the outcome of surgeries and patients' safety. This is potentially a simple, intra-operative, and radiation free method. Differences between the left and right pedicle, which could be due to the operator or the pedicle morphology, were statically tested and considered. Further experiments could clarify the influence of the screw thickness or add to the new findings for non-osteoporotic specimens of this study, because the question remains: what is the minimum BMD level showing a clinical impact and why is the anticipated influence of the BMD not seen?

[1] Galbusera et al., *Eur Spine J* 24(5): 1005–1016. (2015)[2] El Saman et al., *Eur J Trauma Emerg Surg* 39(5):455–460 (2013)[3] Bostelmann et al., *Eur Spine J* 26:181–188. (2017)

Fig. 1

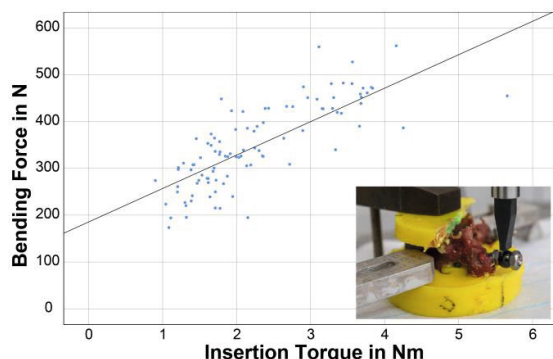


Fig. 1: Linear regression between insertion torque and bending force for all 100 tested pedicle screws with test setup

## V 19

**Neuromuscular control correlates better to the trunk strength ratio in in sitting position compared to single-leg-stance in a healthy population**\*P. Flöbel<sup>1</sup>, J. J. Koltermann<sup>1,2</sup>, K. D. Schaser<sup>1</sup>, A. C. Disch<sup>1</sup><sup>1</sup>Universitätsklinikum Carl Gustav Carus an der Technischen

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**Background:** A well-trained trunk is considered to be a key component in the prevention and therapy of non-specific back pain (BP). Trunk stability is the equilibrium between neuromuscular control (NC) and the trunk strength. The distance covered by the body's centre of gravity (centre of pressure, COP) in a single-leg stance (SLS) is a standard method to quantify NC. However, the data situation regarding the relationship between NC in SLS and back pain is not completely clear. A newer diagnostic approach for NC quantification is COP measurement in a sitting position (SP). It may offer a more sensitive test method to measure NC in BP-patients. Interference factors caused by the lower extremities distorting the COP-Track might be excluded. Until now it hasn't been shown, that NC in SP correlates with the trunk strength (TS)-ratio (RKquot – as an expression of TS). It was hypothesized, that the NC in SP better correlates with the RKquot compared to SLS.

**Methods:** The prospective study involved 38 healthy subjects who were examined in 2019 in a DOSB licensed department of sports medicine. The NC in a SLS and a SP was evaluated by means of the COP measured over 120 sec., and the TS-ratio (resulting from the ratio of flexion to extension, was reproduced as RKquot (Flex/Ext= RKquot)). The NC was recorded with the aid of a balance-board (CSMI, Petaluma, CA, USA). The TS was recorded concentrically over 10 isokinetic repetitions with a dynamometer (Ferstl GmbH, Hemau, Ger.). The description of the data is based with median and the 0.25 and 0.75 quartile. The correlation was analyzed using the correlation coefficient according to Pearson, at a significance level of  $p \leq 0.05$ .

**Results:** For all subjects; gender (16/22, F/M), age (26 [24; 31], and weight (80.1kg [75.3; 85.4]), a significant correlation ( $r=0.62$ ) was found between the NC in a SP and the RKquot (interval between 0.37 and 0.62). Likewise, NC in SP and NC in SLS showed a moderate correlation ( $r=0.42$ ). There is also a moderate correlation between NC in SLS and the RKquot ( $r=0.38$ ). Compared to men, women showed a non-significant increased RKquot  $p=0.06$  (F: 0.50, M: 0.46) combined with a decreased NC (SLS= 727.2/652.9cm, F/M; SP= 139.9/116.3cm, F/M).

**Discussion:** For the first time this study presents NC in different body positions compared to the RKquot. NC in a SP better expressed the association to TS and is a more precise alternative to NC measurement in standing position. This might result from a shorter distance to the center of rotation by eliminating disturbing factors of the lower limbs. As shown previously, women have an increased RKquot due to a reduced extension strength, with a lower NC at the same time. Longitudinal studies comparing healthy people and back pain patients are necessary to underline our findings.

Fig. 1

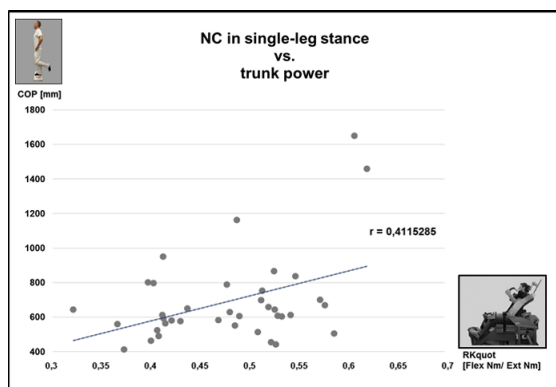
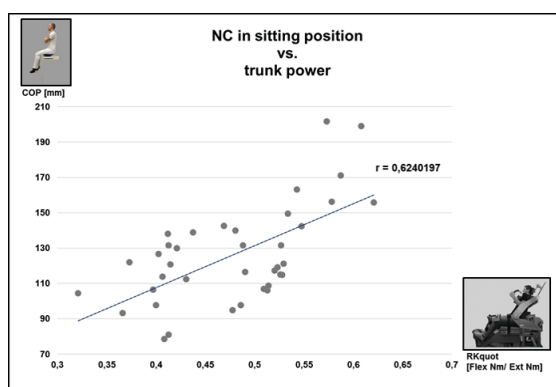


Fig. 2



## V 20

### Assessment of Spinopelvic Mobility before and after Total Hip Arthroplasty

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**Background:** Spinopelvic mobility represents the complex interaction of hip, pelvis and spine. Understanding the interaction is relevant for both arthroplasty and spine surgeons, as a predicted increasing number of patients suffer from hip and spinal pathologies simultaneously. Several studies have reported a higher risk of THA dislocations and inferior outcome in patients with spinal fusion or abnormal spinopelvic mobility. Therefore, the identification of patients with pathologic spinopelvic mobility is important in preoperative workup. This prospective study aims to a) measure spinopelvic parameters in patients with severe osteoarthritis prior to and after THA b) investigate the contribution of the hip, spinopelvic complex and lumbar spine movement from standing to sitting.

**Methods:** In this prospective study 30 patients with osteoarthritis of the hip awaiting THA were enrolled from October to December 2019. Pre- and postoperatively we performed a biplanar low dose EOS image of the entire spine, pelvis and proximal femur in standing and sitting position. Two independent physicians examined the spinopelvic parameters in the lateral radiographs: lumbar lordosis angle (LL), sacral slope (SS), pelvic tilt (PT), pelvic-femoral angle (PFA), acetabular anteinclination (AI) and pelvic incidence (PI). Movement of the lumbar spine was defined as change in LL, spinopelvic mobility as alteration in PT, hip flexion as variation in PFA each from standing to sitting. The difference in PT between standing and sitting allowed the patients to be classified based on spinopelvic motion graded as stiff (< ±

10°), normal (± 10° to 30°), or hypermobile (> ± 30°). Statistical investigations were performed with the paired t-test.

**Results:** Moving from standing to sitting, the hip flexed by a mean of (pre-/ postoperative) 43.6°/ 37.6°, the pelvis tilted backwards (increase in PT) by a mean of 16.2°/ 19.4° and the lumbar spine flexed (reduction in LL) by a mean of 21.7°/ 22.7°. Sitting leads to an acetabular opening (elevation of the AI by a mean of 23°/ 18°). The PI stays unaltered regardless of positional change and as well after THA. There were mainly no significant changes in spinopelvic parameters postoperatively compared to preoperative. Regarding the categorisation of spinopelvic mobility 16.7% (5/30) of the patients showed preoperative stiffness and 10% (3/30) hypermobility.

**Conclusion:** Changing position from standing to sitting only part of the movement is performed by the hip joint with an increasing PT, subsequently increasing AI and flattening of LL. Understanding the spinopelvic interactions is important when performing THA or spinal fusion as they can affect one another. Arthroplasty surgeons should pay attention to the adjustment of the acetabular component in patients with spinopelvic imbalance, while spine surgeons should advise their patients with THA or planned THA of an increased risk of complications after spinal correction surgery.

Fig. 1

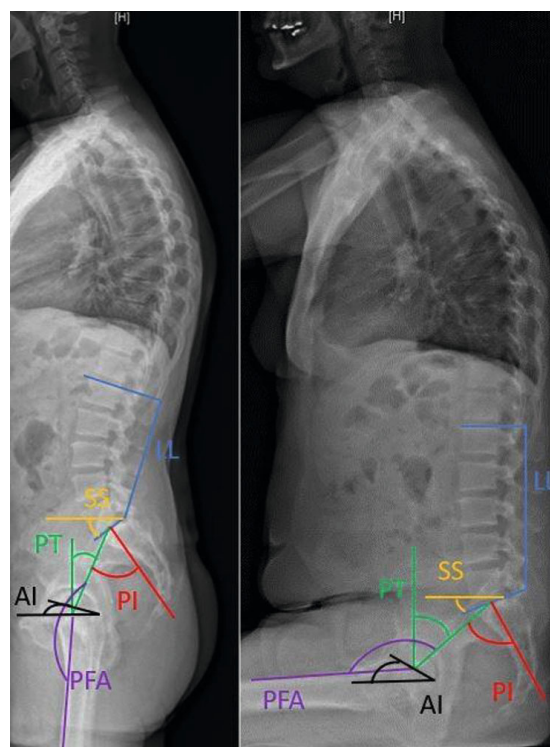


Fig. 2

Biomechanical Parameters	Pre OP Standing	Pre OP Sitting	Change Standing to Sitting	p-value	Post OP Standing	Post OP Sitting	Change Standing to Sitting	p-value	Pre OP Standing	Post OP Standing	Pre OP Sitting	Post OP Sitting	p-value
Mean Lumbar lordosis° (SD)	52.7 (27.5)	51.2 (15.5)	21.7 (14.1)	<0.01*	51.6 (14.8)	29 (15.3)	22.7 (14.5)	<0.01*	52.7 (17.5)	51.6 (14.8)	0.3 (15.5)	29 (15.3)	0.16
Mean sacral slope° (SD)	40.1 (15.5)	23.4 (12.3)	17 (11.9)	<0.01*	39.7 (14.4)	21.2 (12.2)	18.4 (14.5)	<0.01*	40.1 (15.5)	39.7 (15.5)	0.4 (14.4)	21.2 (12.2)	0.11
Mean pelvic tilt° (SD)	34.1 (9.3)	31 (8.8)	36.2 (8.1)	<0.01*	33.6 (7.6)	32.6 (11.2)	19.4 (13.7)	<0.01*	34.1 (9.3)	33.6 (9.2)	0.3 (7.6)	31 (8.8)	0.18
Mean pelvic femoral angle° (SD)	170.7 (9.1)	126.1 (12.9)	43.6 (17.6)	<0.01*	171.4 (5.7)	132.8 (11.4)	37.6 (13.7)	<0.01*	170.7 (9.1)	171.4 (9.1)	0.3 (5.7)	126.1 (12.9)	<0.01*
Mean pelvic incidence° (SD)	55 (12.9)	57.6 (13.7)	3.9 (3.9)	0.02*	56.3 (13)	55.2 (11.5)	3.9 (2.7)	0.31	55 (12.9)	56.3 (13)	0.19 (13.7)	57.6 (13.7)	0.16
Mean acetabular anteinclination° (SD)	35.3 (9)	39.2 (9.5)	23 (12.3)	<0.01*	25.9 (8.4)	43.7 (7.4)	18 (7.3)	<0.01*	35.3 (9)	25.9 (8.4)	<0.01*	39.2 (9.5)	0.03*

## V 21

**Muscle fatigue and pelvic acceleration during a 30-minute walking test are related to muscle atrophy in patients with symptomatic lumbar spinal stenosis**

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**Introduction:** In patients with symptomatic lumbar spinal stenosis (sLSS) the narrowing of the spinal canal leads to pain and functional impairments in walking and balance. Moreover, paraspinal muscle atrophy has been observed in patients with sLSS and associated with the patients' functional status.<sup>3</sup> The aim of this study was to investigate the relationship between clinical scores, severity of stenosis and paraspinal muscle atrophy with back muscle fatigue and pelvic acceleration during a 30-minute walking test in patients with sLSS.

**Methods:** Eighteen patients with sLSS (age: 71.8±8.5 years, BMI: 23.8±3.6 kg/m<sup>2</sup>, Oswestry disability index (ODI): 31 ± 14) performed a 30-minute walking test in a 200m long hallway. In case of onset of symptoms that caused patients to pause, the test was ended prematurely and the duration was noted. Every 3 minutes, pain was assessed on a numeric rating scale (0 to 10) and pelvic acceleration was measured for 60s using an inertial sensor placed on the sacrum (RehaGait, Hasomed, Germany). The root mean square (RMS) of the 3D acceleration signal was calculated for each direction and normalized to walking speed. Muscle activation of gluteus medius, multifidus and erector spinae muscles was measured continuously using surface electromyography (EMG; myon, Switzerland). Median EMG frequency was calculated for 20s bins with 10s overlap during the entire test. Fatigue was defined as the slope (b) from the linear regression model fitted to median EMG frequency over time. Stenosis severity was defined using Schizas grading<sup>4</sup>. Muscle atrophy using the Goutallier classification<sup>5</sup> in transverse MRI images of the most affected level. Relationships between pain, ODI, stenosis severity, muscle atrophy with muscle fatigue and pelvis acceleration were calculated using Spearman's correlation coefficients (P<0.05).

**Results:** The average walking duration was 22.1±10.9 min (61% of patients walked for 30min) and pain level was 2.7±2.1 at the start and 4.4±2.1 at the end. Severity of muscle atrophy correlated significantly with duration of walking test (R=−.499), fatigue of multifidus (R=−.597), and mediolateral pelvic acceleration (R=−.515). Severity of stenosis level and ODI score did not significantly correlate with muscle fatigue or pelvis acceleration.

**Discussion:** Patients with greater muscle atrophy walked for a shorter period of time, showed greater multifidus muscle fatigue and higher pelvic acceleration. This suggests that the severity of functional limitations in patients with sLSS is related to fatty atrophy of the paraspinal muscles. Hence, early detection of muscle atrophy and subsequent strengthening could improve patients' symptoms.

**References:** [1] Tomkins-Lane & Battie. J Back Musculoskelet Rehabil. 2013;26:345-52; [2] Yarjanian et al. PM & R. 2013;5:39-44; [3] Fortin et al. Eur Spine J. 2017;6:2543-51; [4] Schizas et al. Spine. 2010;35:843-52; [5] Goutallier et al. Clin Orthop Rel Res. 1994;304:78-83

## V 22

**Whole Body Vibration in Adolescent Idiopathic Scoliosis**

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**Objective:** The aim of this study was to evaluate the effect of physiotherapeutic scoliosis specific exercises (SSE) combined with SSE on a side-alternating whole body vibration platform (WBV) as a home-training program in girls with adolescent idiopathic scoliosis (AIS).

**Methods:** This study was an investigator blinded randomized controlled trial, which has been previously published. Participants: 40 female AIS patients aged 10 to 17 years, wearing a brace and performing regular PSSE were randomly assigned to two groups. The intervention group performed an additional home-based PSSE program on a WBV platform for 6 months. Exercises were standing, sitting and two different kneeling positions (each 3 minutes) five times per week. The control intervention was regular PSSE (treatment as usual). Main Outcome Measure(s) were the Cobb angle measured at start and after six months by MRI. A clinically relevant effect was estimated at a change of 5°. The onset of menarche was documented for sub-group analysis.

**Results:** The major curve (MAC) in the WBV group decreased significantly by -2.3° (SD± 3.8) (95% CI -4.1 to -0.5; P=.014) compared to the difference in the control group of 0.3° (SD±3.7) (95% CI-1.5 to 2.2; P=.682). The difference between groups was significant (p=.035). Clinical relevance for MAC: In the WBV group 20% (n=4) improved by ≥5°, 75% (n=15) stabilized and 5% (n=1) deteriorated. In the control group 0% (n=0) improved, 89% (n=16) stabilized and 11% (n=2) deteriorated. Subgroup analysis showed the clinically largest change in the "before-menarche" subgroup.

**Discussion:** This pilot study showed that an additional home-based PSSE performed on a sWBV platform for six months counteracts the progression of scoliosis in girls with AIS wearing a brace; especially before the onset of the menarche. A study protocol on a confirmatory trial on PSSE on a WBV platform in young girls with idiopathic scoliosis before prescription of a brace will be discussed.

## V 23

**Development of Thoracic Kyphosis after Posterior Correction and Fusion of Adolescent Idiopathic Scoliosis – a radiological analysis of 100 cases**

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**Introduction:** Posterior correction and fusion for adolescent idiopathic scoliosis provides good results in the coronal plane. But pedicle screw based instrumentations tend to flatten the spine. With derotation the anterior column is lengthened which sacrifices kyphosis. Although there is a paucity of evidence to prove that this affects long-term outcome and quality of life, it is logical to assume that thoracic kyphosis (TK) restoration may optimize global sagittal alignment and slow down lumbar and cervical disc degeneration.

**Methods:** Radiographs of 100 consecutive patients that underwent posterior correction and fusion for adolescent idiopathic scoliosis (AIS) at a single center were analysed. 5.5mm titanium or cobalt chromium rods were used. TK was measured preoperatively and two years postoperatively for the whole group, and separately for hypo-, normo- and hyperkyphotic (according sagittal modifiers of the Lenke classification) patients. A one-sided one-sample t-test was performed to compare pre- and postoperative values.

**Results:** For all patients mean TK significantly decreased by 3.8° ± 3.4 (p=0.005). For hyperkyphotic patients (n=9) mean TK significantly decreased by 18.9° ± 3.8 (p=0.006). For normokyphotic patients (n=75) mean TK significantly decreased by 3.9° ± 3.2 (p=0.001). For hypokyphotic patients (n=16) mean TK significantly increased by 4.9° ± 2.4 (p=0.005).

**Discussion:** The results are ambivalent which is consistent with the literature. Except for the hyperkyphotic group the differences are within or close to the range of a measurement error. The main conflict of implant stiffness versus lengthening the anterior column with derotation remains unsolved. Additionally, it is difficult to define an optimal TK for the individual patient. Even with translation maneuvers and the use of cobalt chromium rods creation of kyphosis is difficult. However, in patients that are already hypokyphotic it is possible to achieve good coronal correction without sacrificing additional kyphosis.

## V 24

### Vertebral Body Tethering Positively Influences the Sagittal Profile

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**Introduction:** While the results of Vertebral Body Tethering (VBT) on coronal profile have been investigated in numerous study, the same cannot be said for the effects of VBT on the sagittal plane. In particular, the unclear effects of VBT on lumbar lordosis limits the use of this technique in the lumbar spine. Aim of our study was to analyze the effects of VBT on sagittal parameters.

**Materials and Methods:** Data of all skeletally immature patients (Risser  $\leq 4$ ) who underwent VBT at our institution and had a minimal follow-up of one year were retrospectively analyzed. Radiographic analysis included sagittal profile as classified by Abelin-Genevois, thoracic kyphosis (TK, T1-T12), lumbar lordosis (LL, L1-S1), pelvic tilt (PT), pelvic incidence (PI), and sagittal vertical alignment (SVA) preoperatively, and at the last follow up.

**Results:** Data from 48 patients were available (age  $14.1 \pm 1.3$  years, 6 male). Mean follow up was 15.5 months. PI was  $45.7 \pm 13.5^\circ$ . Before VBT, 21 patients had a type 1 sagittal profile, 7 were 2a, 10 were 2b and 10 were 3. At the last follow up, type 1 and 2a patients were all type 1, all type 2b and 3 patients maintained the same sagittal profile except one patient, who improved from 2b to 2a. Radiological parameters before surgery and at the last follow-up are summarized in Table 1. In the separate analysis of LL in patients with lumbar instrumentation, LL increased from  $53.3 \pm 11^\circ$  to  $57.3 \pm 12.3^\circ$  ( $P=0.02$ ). Observing only patients type 2b and 3, despite maintenance of same sagittal profile, there was an improvement in TK (from  $28.4 \pm 14^\circ$  to  $33.4 \pm 15.1^\circ$ ), LL (from  $49.1 \pm 8.4^\circ$  to  $52.4 \pm 11.1^\circ$ ) and SVA (from  $17.1 \pm 32.6^\circ$  to  $52.4 \pm 11.1^\circ$ ).

**Discussion:** The presented study suggested a positive effect of VBT on sagittal parameters. Patients with a type 2a profile profited the most from VBT and gained a physiologic profile. Overall, all sagittal parameters improved after VBT. Furthermore, LL increased after VBT, ruling out a possible kyphosing effect of ventral instrumentation on LL. Despite maintaining the same sagittal profile, also patients 2b and 3 experienced an improvement of sagittal parameters. These findings may be relevant in the identification of the ideal candidate for VBT.

Table 1: Summary of radiological parameters before surgery and at last follow-up, expressed as Mean  $\pm$  Standard Deviation

Fig. 1

	Before surgery	Last follow-up	P values
Cobb T	$57.2 \pm 17.4^\circ$	$32.9 \pm 12.9^\circ$	$P < 0.0001$
Cobb L	$49.2 \pm 15.3^\circ$	$27.5 \pm 13.5^\circ$	$P < 0.0001$
PI	$45.7 \pm 13.3^\circ$	-	-
TK	$33.3 \pm 14^\circ$	$37.6 \pm 12.9^\circ$	$P = 0.01$
LL	$54.1 \pm 10.8^\circ$	$56.3 \pm 11.5^\circ$	$P = 0.08$
SVA	$9.5 \pm 32.2$ mm	$4.8 \pm 25.7$ mm	$P = 0.42$
PT	$9.9 \pm 8.9^\circ$	$10.9 \pm 8^\circ$	$P = 0.86$

## V 25

### Is the instrumentation and fusion to L5 eligible in severe scoliosis and cerebral palsy to significantly effect the pelvic obliquity after 3 years of follow-up?

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**Introduction:** The horizontal orientation of the pelvis within the instrumented correction and fusion in severe scoliosis and cerebral palsy (CP) is an important goal of corrective spinal surgery. Despite the prolonged OR time, hardware prominence, increased infection and pseudarthrosis rates the current literature describes the necessity of instrumentation to the pelvis to effect pelvic obliquity (PO).

In a first evaluation one year postop we were able to show that in moderate PO stopping fusion at L4 or L5 yields satisfactory results. In severe lumbar curves with considerable and rigid PO such a technique only results in insufficient correction of PO. The aim of this follow-up study is the evaluation of the development of the lumbar curve and correction of PO after 3 years in attention to stability of correction and possible influencing factors.

**Material/Method:** Retrospective radiologic evaluation of 42 ICP-scoliosis patients who underwent dorsal instrumented correction and fusion stopping at L4 or L5 (2011-2018) within an average follow-up of 2.8 years.

Only the main curve/ lumbar curve was taken into account to evaluate the influence on PO.

**Results:** Preop. Cobbangle averaged  $92.23^\circ$  ( $56-155^\circ$ ) (correction by traction 33,1%) and was significantly corrected in the follow-up of 2,8 years to  $41.35^\circ$  ( $12-84^\circ$ , 57,5% correction). Preop PO averaged  $19.12^\circ$  ( $0-42^\circ$ ) and was corrected to  $10.46^\circ$  ( $0-28^\circ$ , 45,0% correction) ( $p < 0,05$ ). No significant loss of correction was seen regarding PO and lumbar Cobbangle directly postop. and after 3 years (postop.  $\emptyset$  Cobbangle:  $42.8^\circ$ , postop.  $\emptyset$  BST:  $9.2^\circ$ ,  $p > 0,05$ ). In 6 pts. a PO of more than  $10^\circ$  persisted, more than  $20^\circ$  in additional 6 pts. A preop. correction of  $PO \leq 10^\circ$  through traction resulted in constant values of  $PO \leq 10^\circ$  in 82% in the follow-up whereas PO remaining  $\geq 10^\circ$  after preop. traction led to 43% of the pts. with a  $PO \geq 10^\circ$  in the follow-up.

The hip joint on the concave side of the main/ lumbar curve showed a significant lower CE-angle ( $26.1^\circ$  vs.  $39.3^\circ$ ) and higher index of dysplasia (26,9% vs. 10,4%) ( $p < 0,05$ ). The extent of dysplasia of the hip joint had no significant influence on the postoperative PO correction.

**Conclusion:** This follow-up study 3 years postop was able to confirm the results of the former investigation that a moderate PO does not require iliac fixation to receive a horizontal orientation of the pelvis. Severe lumbar curves with minor correction of PO in traction radiography implicate unsatisfactory horizontalisation of the pelvis.

The hip joint on the concave side of the lumbar deformity shows a significantly higher grade of dysplasia through missing containment.

## V 26

### Can artificial intelligence support or even replace physicians in measuring the sagittal balance? – a validation study on preoperative and postoperative images of 170 patients

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**Objective:** The "sagittal balance" (SB) plays an important role in the surgical treatment of spinal disorders. Current approaches to determine SB parameters suffer from time-consuming manual measurements. The aim of the research presented here is the detailed evaluation of the reliability of a new, fully automated algorithm based on artificial intelligence (AI) for the determination of radiographic SB parameters.

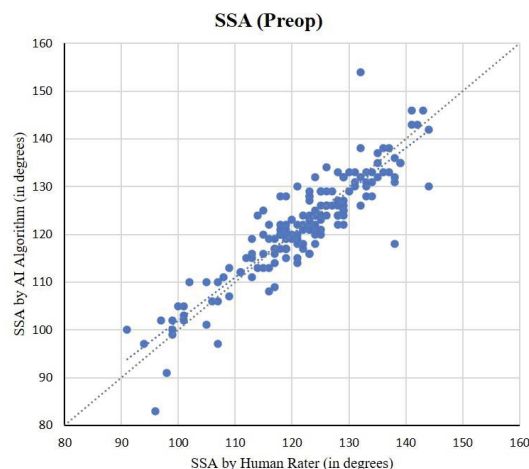
**Methods:** A total of 170 preoperative and 170 postoperative sagittal full body radiographs were measured by two independent human raters (R1, R2; fully blinded) and twice by one rater (R1a, R1b) to determine inter- and intra-rater reliability. The following radiographic parameters were included in the analysis: pelvic incidence, pelvic tilt, sacral slope, L1-S1 lordosis (LL) and the spino-sacral angle (SSA). Subsequently, all 340 X-ray images were analyzed fully automatically by an AI algorithm (R-KI) based on two "Convolutional Neural Networks" (CNN). In a first step, the algorithm determines all required anatomical entities (C7, L1, sacrum and femoral heads). Secondly, anatomical reference landmarks were automatically placed onto these entities allowing the calculation of the parameters. The algorithm was trained on 541 anonymized lateral radiographs.

To evaluate the agreement in determining the SB, the mean error (95% confidence interval (CI), standard deviation) between all raters was calculated. Furthermore, the intra- and inter-rater reliability between human raters and the AI algorithm was assessed using intra-class correlation coefficient (ICC, Shrout and Fleiss, 1979) to quantify the degree of absolute agreement. ICC values larger than 0.75 were considered excellent (Cicchetti, 1994).

**Results:** ICC values for the assessment of the intra- (range: 0.88–0.97) and inter-rater (0.86–0.97) reliability of human raters are excellent. The algorithm is able to determine all parameters in 95% of all pre- and in 91% of all postoperative images with excellent ICC values (PreOP-range: 0.83–0.91, PostOP: 0.77–0.89). Exemplarily for R1a vs. R-AI, mean errors are smallest for the SSA (PreOP:  $0.4^\circ$  (95%-CI:  $-0.4^\circ$ – $1.2^\circ$ ; Fig. 1); PostOP:  $1.0^\circ$  ( $0.2^\circ$ – $1.8^\circ$ )) and largest for LL ( $3.9^\circ$  ( $3.0^\circ$ – $4.9^\circ$ );  $4.8^\circ$  ( $3.7^\circ$ – $5.8^\circ$ )).

**Conclusion:** A new, fully automated algorithm that determines SB parameters with an excellent reliability, in particular for preoperative images, was thoroughly validated. The presented solution will significantly relieve physicians from time-consuming routine work and assist in avoiding error-prone manual measurements. The inclusion of additional training material can further improve the reliability, especially for postoperative images, where implants make the automatic determination more challenging.

**Fig. 1**



## V 27

### Single- vs. dual-attending strategy for spinal deformity surgery – 2-year experience and systematic review of the literature

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**Background:** Adult spinal deformity (ASD) surgery is complex and associated with high morbidity and complication rates. There is growing evidence in the literature describing the beneficial effects of a dual-attending care model. We developed a joint neuro-ortho collaboration in August 2017 to mutually operate on patients with ASD.

**Material/Methods:** Our series was reviewed and compared to a matched control population operated by a single attending. We set out to report our 2-year experience with the dual-attending strategy. We analyzed estimated blood loss (EBL), transfusions, length of stay (LOS), discharge disposition, complication rates, emergency room visits and readmissions, subjective health-status improvement, disability (ODI) and pain (VAS) at last follow-up. In addition, the pertinent literature for dual-attending spinal deformity correction was systematically reviewed. No funding was received. The authors report no conflicts of interest.

**Results:** Nineteen of 254 consecutively operated thoracolumbar fusion cases from January 2017 to June 2019 comprised the study group (7.5%; mean age 65.1 years, 68.4% female, ODI 44.5, VAS pain 6.8). They were matched by age, sex, anesthesia risk, BMI, smoking status, ODI, VAS pain, prior spine surgeries, and basic operative characteristics (type of interbody implants, instrumented segments, pelvic fixation) to nineteen control subjects (all  $p > 0.05$ ). There was a trend towards less EBL (mean 763 vs. 1524ml,  $p = 0.059$ ), fewer intraoperative red blood cell transfusions (mean 0.5 vs. 2.3,  $p = 0.079$ ) and fewer 90-day readmissions (0 vs. 15.8%,  $p = 0.071$ ) in the dual-attending group. LOS and discharge disposition were similar, as were the rates of any complications  $< 30$  days, 90-day ER visits, reoperations, ODI and VAS pain at last follow-up (all  $p > 0.05$ ). At last follow-up, 94.7% vs. 68.4% of patients in the dual- vs. single-attending group stated their health-status had improved ( $p = 0.036$ ). Five of eight prior articles on spinal deformity correction found lower EBL in dual-attending cases (62.5%), six (75%) reported significantly lower operation length. The literature contained differing results with regards to complication- or reoperation-sparing effects of dual-attending cases. Similar clinical outcomes of dual- vs. single-attending cases were reported.

**Discussion:** Establishing a dual-attending care management platform for ASD correction was feasible in our institution. Even though our own institutional results were mostly comparable, dual-attending strategies had a positive safety and outcome profile in the systematic literature review.

## V 28

### Prevalence of concomitant spine injury in patients with traumatic brain injury and association with outcome: a CENTER-TBI analysis

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**Introduction:** Spine injury is highly prevalent in poly-trauma patients. However, less is known about the prevalence of serious spine trauma in patients with traumatic brain injury (TBI). In this study, we used the CENTER-TBI database to assess the prevalence, characteristics, and outcome of patients with traumatic brain injury and concurrent spine trauma.

**Methods:** Data from the European multi-center, observational, longitudinally collected CENTER-TBI core study were analyzed. Adult TBI patients ( $\geq 18$  years) presenting with a concomitant, isolated spine injury were included. Spine injury was defined by an Abbreviated Injury Scale (AIS) of  $\geq 3$  (at least serious injury) in the cervical, thoracic, or lumbar spine. To study the impact of spine injury separately from poly-traumatic injuries, patients were excluded when also suffering from serious injuries (also defined by an AIS of  $\geq 3$ ) in other body regions. For outcome analysis, we used propensity score matching to create a comparison group of TBI patients without spine trauma that was pair-matched to the study cohort by age, sex, GCS, intracranial operations, CT abnormalities, and ASAPS class.

**Results:** From the 4255 adult patients within the CENTER-TBI core study, a total of 164 (4%) suffered from a concomitant

isolated spine trauma of at least serious severity. The median age was 53 years (IQR: 37–66 years) and 116 (70%) were males. Alcohol intoxication was confirmed or suspected in 24% of patients. At hospital presentation, severe TBI (GCS 3–8) was present in 26% of patients, while moderate or mild TBI was documented in 10% and 62% of cases, respectively. Spine injuries were located in the lumbar spine in 34 patients (21%), in the thoracic spine in 52 patients (32%), and in the cervical spine in 106 patients (65%). In total, 57% of patients were admitted to the intensive care unit. Surgical spine stabilization was performed in 32 patients (20%). The median hospital length-of-stay was 9 (3–20) days. After six months, mortality was 13% and only 23% of patients regained full functional recovery (GOSE = 8). When compared to the matched cohort without spine trauma, significantly fewer patients regained full recovery and the length-of-stay was significantly longer. The overall mortality however was not significantly different between the two groups.

**Discussion:** Concurrent, isolated, serious spine trauma was identified in 4% of TBI patients in the CENTER-TBI study. While mortality was not found to be increased, significantly fewer patients with both injuries regained full recovery. Furthermore, higher ICU admission rates and longer hospital stays could be observed.

## V 29

### Evaluation of factors predisposing to posttraumatic syringomyelia

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**Introduction:** Post-traumatic syringomyelia (PTS) is a rare long-term complication of spinal cord injuries. PTS develops on average 3 to 15 years after the trauma and can cause a secondary deterioration in neurological functions. Despite the low incidence, the maintenance of residual neurological functions in spinal cord injuries is of immense individual and socio-economic importance. Strategies for the prophylaxis of PTS are based on the earliest possible diagnosis of PTS, with the focus on the identification of predisposing factors.

**Material/Methods:** Retrospective analysis of 51 cases with (group 1) and 28 cases without (group 2) syrinx formation after a spinal cord injury. Unmatched cohort study from both groups and case-control study with matching of 22 cases from each group were carried out. Clinical examination parameters: localization and initial therapy of the injury, expression of the neurological deficits (ASIA score), spinal canal width and kyphosis in the area of the injury. Descriptive evaluation and comparison of the groups with non-parametric test methods. Binary logistic regression analysis for risk factor determination (SPSS Statistics 24, IBM).

**Results:** In the unmatched cohort analysis, the only significant difference in iatrogenic parameters was found in post-traumatic kyphosis in the trauma area (mean 24.1 ° in G1 vs. 11.3 ° in G2;  $p = 0.003$  logReg) and the proportion of initial surgical therapy (49% in G1 vs. 96.4% in G2;  $p = 0.023$  logReg). These parameters remained significantly different in the case-control analysis (mean segmental kyphosis: 28.6 ° in G1 vs. 12.32 ° in G2;  $p = 0.001$  logReg and proportion of initial surgical therapy: 54% in G1 vs. 90.9 % in G2;  $p = 0.035$  logReg). There is also a clear trend towards the negative influence of a lower spinal canal width (mean 8.3mm in G1 vs. 10.7mm in G2;  $p = 0.08$  logReg).

**Discussion:** Due to the retrospective approach, the low number of cases and moderate power of the analysis, the results can only be generalized to a very limited extent. A higher risk of developing PTS appears to be most likely when there is a combination of poor neurological initial status (ASIA grade A) and poor sagittal profile (especially in the case of kyphotic deformity in the injury area) and a reduced spinal canal width. Unfavorable individual demographic and trauma-specific aspects cannot be influenced – the best possible clearance of the spinal canal and correct restoration of the spinal profile, however, can. If surgery is carried out after spinal injury, at least these two parameters should be optimized to prevent PTS. Certain clinical constellations (poor initial ASIA status + kyphotic deformity + narrowed spinal canal) should lead to a regular search for early signs of PTS.

## V 30

### Differentiated Treatment of Thoracolumbar Hyperextension Injuries – Results of a Prospective Cohort Study

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**Introduction:** Hyperextension injuries [HEIs] of the thoracolumbar spine are supposed to be rare, accounting for less than 1% of all thoracolumbar fractures. Corresponding to this, the literature only holds small numbers of case reports and studies with small numbers of participants.

**Material/Methods:** Between 1/1997 and 12/2018 154 patients with 165 HEIs of the thoracolumbar spine (41 women and 113 men, average age at the time of the accident  $70.3 \pm 13.5$  years, range 25 – 93 years) were prospectively recorded and followed up in a standardized manner. Computed tomographic scans and MRI scans were evaluated. The injury patterns of the anterior column were differentiated into 3 groups: transosseous, transdiscal and combined forms, in which both the disc space and the vertebral body were affected. At the posterior column, osseous and ligamentous injuries were differentiated. A classification system with 6 different types of HEIs resulted from the combinations of these groups (fig. 1). In addition, pre-existing changes in the axis skeleton, the type of care, complications, time of bony healing/fusion and survival rates were analyzed. Values were expressed as the mean and standard deviation of the mean.

**Results:** A tenfold increase in patients with HEIs was observed in the past 20 years in a level I trauma center. 122 (74%) HEIs were associated with diffuse idiopathic skeletal hyperostosis [DISH] and 23 (14%) with ankylosing spondylitis. Only 9 (5%) of these injuries involved patients without ankylosing spinal disease. HEIs in DISH and ankylosing spondylitis patients showed highly significant differences in the injury morphology (fig. 2). 120 of the 165 (72%) fractures were treated operatively with posterior instrumentation or spondylodesis, which covered an average of 3 movement segments (range 1–6). 45 type 1–3 HEIs in DISH were treated conservatively in absence of neurological deficit. 12 of 165 patients (7%) died within the first 3 months after injury, 5 more within the first year. 123 (83%) patients have been followed up for an average of  $31.3 \pm 12.7$  months after injury. The revision rate of patients who were treated surgically was 6%. Within the first year, 96% of the surgically treated and 98% of the conservatively treated hyperextension injury healed and remained stable. There was no neurological deterioration in any case of the conservatively treated patients. In no case conservative management had to be stopped in favor of surgery, however.

**Discussion:** To our knowledge, this study is by far the largest cohort of patients with HEIs of the thoracolumbar spine. The study provides important data for epidemiology, localization, accompanying pathologies, fracture morphology and the need for therapy. Hyperextension injuries are not a single entity, but must be treated differently.

**Fig. 1**

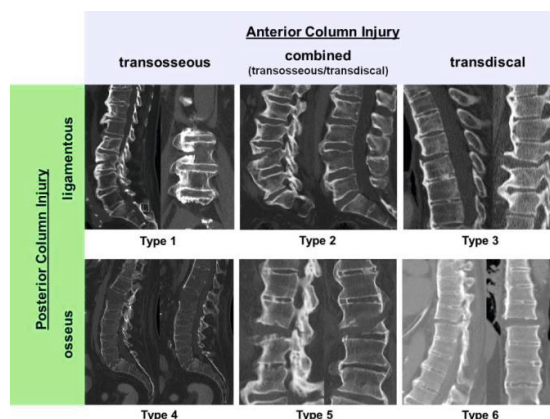


Fig. 2

		Anterior Column Injury		
		transosseous	combined (transosseous/transdiscal)	transdiscal
Posterior Column Injury	ligamentous	<b>Type 1</b> <b>37</b> 36 DISH 0 AS 1 SD 0 WASD	<b>Type 2</b> <b>35</b> 30 DISH 0 AS 4 SD 1 WASD	<b>Type 3</b> <b>33</b> 26 DISH 0 AS 1 SD 6 WASD
	osseous	<b>Type 4</b> <b>43</b> 19 DISH 19 AS 4 SD 1 WASD	<b>Type 5</b> <b>10</b> 6 DISH 3 AS 1 SD 0 WASD	<b>Type 6</b> <b>7</b> 5 DISH 1 AS 0 SD 1 WASD

AS ankylosing spondylitis; SD spondylolysis deformans; WASD without ankylosing spinal disease

## V 31

### Long-term outcome of ventral stabilization of unstable vertebral fractures of the thoracolumbar junction over a period of at least 10 years

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**Introduction:** The isolated or additive ventral treatment of unstable vertebral fractures at the thoracolumbar junction is a well-established form of therapy. The long-term outcome, however, is still not documented sufficiently. The purpose of this study is to analyze the long-term outcome and to compare the different forms of ventral stabilization, monosegmental or bisegmental, and with or without an additive ventral plate osteosynthesis.

**Material & Methods:** In this retrospective cohort study at a level I spine center, patients over the age of 18 were examined who had suffered an unstable vertebral body fracture (type AOSpine A3, A4, B, and C) of the thoracolumbar junction between January 1, 2004 and December 31, 2006 due to an adequate trauma and who received either an isolated or additive ventral treatment using an expandable titanium cage. Patients with pathological fractures, fractures of other height localization and patients who did not receive primary surgical treatment within 30 days after the trauma were excluded. The type and timing of surgery were analyzed. In addition, a follow-up was performed after at least 10 years. The Oswestry Disability Index (ODI) score was used as the primary outcome parameter. Further clinical parameters analyzed were pain (NRS; 0 – 10) and patient satisfaction with the treatment (NSR). The radiological outcome parameter was the loss of correction with respect to the bisegmental kyphotic endplate angle.

**Results:** A total of 66 patients with an average age at the time of ventral treatment of 44 years ( $\pm 12.8$ ; 48 ♂, 18 ♀) were included. There were 34 L1, 19 Th12 and 12 L2 fractures as well as one Th11 fractures. Of these, the majority were incomplete (36%) and complete burst fractures (33%) and B fractures (23%). C fractures accounted for 8% of cases. In the vast majority of patients, two-stage dorsoventral treatment was performed (94%), in 27 cases ventral monosegmental (41%) and 39 cases (59%) bisegmental. In addition, 16 patients (24%) were treated with a ventral plate osteosynthesis. Removal of the dorsal implant was performed in 13 patients (20%). Overall, data on outcome parameters was obtained from 50 patients (76%) after at least 10 years (average: 12.6 years). The average ODI was 20.5% ( $\pm 17.4$ ). The average pain was 3.3 ( $\pm 3.0$ ), the average patient satisfaction was 7.1 ( $\pm 3.0$ ). The average bisegmental kyphotic correction loss was 5.6° ( $\pm 4.3$ ). Comparing the different ventral treatment options, the patients who received ventral bisegmental stabilization had significantly worse ODI values ( $p=0.031$ ), but also suffered from a more severe fracture ( $p=0.003$ ).

**Conclusion:** Overall, more than 10 years after an isolated or additive ventral stabilization, the clinical results are mostly satisfactory with only minor limitations and minor loss of correction.

## V 32

### Risk factors for failure in conservatively treated osteoporotic vertebral fractures – a systematic review

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**Background:** Osteoporosis is one of the most common diseases of the older age, whereby vertebral body fractures are in many cases the first manifestation. Even today the consequences for patients are underestimated. Therefore, early identification of therapy failures is essential. In this context the aim of the present systematic review was to evaluate the current literature with respect to clinical and radiographic findings that might predict treatment failure.

**Methods:** We conducted a comprehensive, systematic review of literature according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) checklist and algorithm, including Pubmed and Google scholar database.

**Results:** After literature search 724 potentially eligible investigations were identified. At the end 24 studies with 3044 participants and a mean follow-up of 11 months (range 6–27.5 months) were finally included. Patient-specific risk factors were age > 73 years, bone mineral density  $t < -2.95$ , BMI > 23 and a modified frailty index over 2.5. Beside this a couple of radiological and fracture specific risk factors could be identified, like involvement of the posterior wall, initial height loss, midportion type fractures, development of an intravertebral cleft, fractures at the thoracolumbar junction, fracture involvement of both endplates, different morphological types of fractures (bow-shaped type fractures, projecting type fractures, swelled front type fractures) as well as specific MRI findings. Furthermore, a correlation between sagittal spinal imbalance and treatment failure could be demonstrated.

**Discussion:** In conclusion this systematic review has gathered various factors that predict treatment failure in conservatively treated osteoporotic fractures. In those cases additional treatment options as well as a non-conservative treatment should be considered in addition to consequent follow-up examinations.

## V 33

### Unstable Jefferson burst fractures: intraoperative stability testing after posterior atlas ring osteosynthesis enables patients to be identified without the need for C1 / C2 stabilization

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**Introduction:** Posterior direct atlas or C1 ring osteosynthesis (C1-RO) is an operative treatment option for unstable Jefferson burst fractures (JBF) with possible C1-C2 function recovery. Since Ruf et al. first described anterior C1-RO in 2004, also posterior and combined C1-RO have been described. Two biomechanical studies have proven that despite ruptured transverse atlantal ligament (TAL), reduction and C1-RO can provide secondary stabilizers with sufficient effectiveness. This work shows the results of the posterior C1-RO and C1-C2 osteosynthesis, which were based on the decision of our previously described intraoperative stability test (Fig. 1) after reduction and C1-RO.

**Method:** The clinical findings and radiological results (static CT-scan, Functional x-ray, clinical head rotation, reported pain) of 5 cases (47–75 years; mean 61 years) with unstable JBF from 2017–2019 with posterior C1-RO or C1-C2 osteosynthesis with therapy decision after intraoperative reduction and C1-RO and stability test C1-C2 were analyzed.

**Results:** A total of 5 patients with JBF were subjected to an intraoperative stability test after attempted reduction and C1-RO from 2017–2019. The operation was carried out as C1-RO in 4 patients, in one case it was expanded to a C1 / C2 osteosynthesis by means of a Harms / Goel construct with a cross connector (Fig. 2). In all cases of C1-RO, bony stabilization of the atlas ring occurred during the course (3–12 Months postoperatively). The anterior atlantodental distance in the functional images did not increase during the course and the patients were free of pain. Therefore no case with C1-RO had to undergo further stabilization. In 2 out of 4 cases with C1-RO there was an incomplete reduction of the atlas ring intraoperatively, but there was no correlation between reduction and rotation of the head.

**Discussion:** The intraoperative stability test C1-C2 in the treatment of unstable JBF with repositioned and fixed C1-ring by means of posterior direct C1-RO enables the delimitation to a necessary extension of the osteosynthesis (or a fusion) to C2 (e.g. by a C1 / C2 Harms / Goel construct with cross connector, see Fig.2). As a rule, the C1-RO comes to a bony fusion of the atlas ring, and the anterior atlantodental distance in functional images does not increase in the course. An incomplete repositioning of the atlas ring is not related to clinical function recovery. Still there is a need for better repositioning tools, to achieve full reposition of the atlas ring from posterior.

Fig. 1

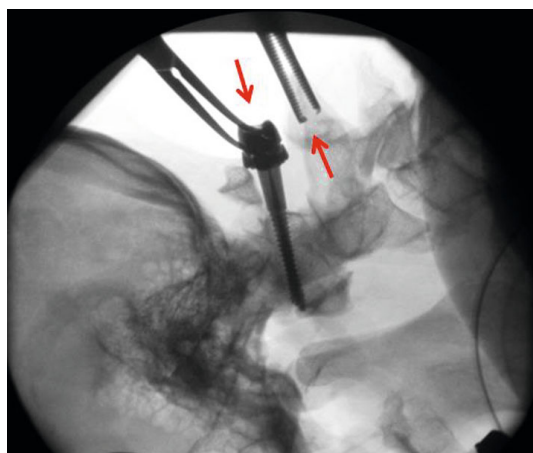
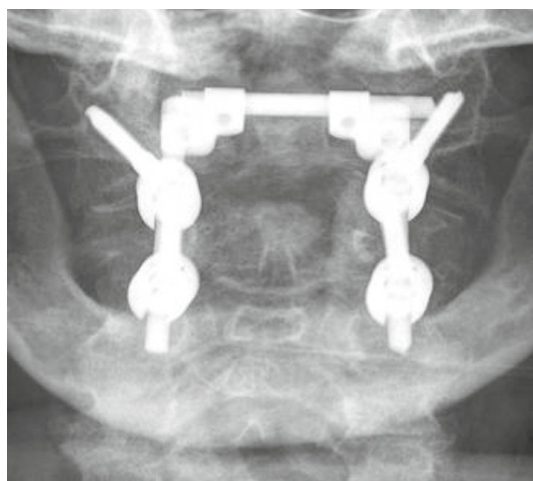


Fig. 2



### V 34

#### Safety, effect and feasibility of percutaneous SI-screw with and without augmentation – a 15-years retrospective analysis on over 640 screws

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**Introduction:** Percutaneous sacroiliac-screw (SI-screw) fixation is a well-established procedure for the minimal invasive treatment of posterior pelvic ring fractures to restore stabilization between the spine and the pelvic ring. There are yet only small case series describing clinical results of percutaneous SI-screw fixation. [1] Aim of this study was to provide sufficient data about risk, safety and immediate effects of SI-screw fixation with and without augmentation.

**Methods:** The present single center retrospective cohort study investigates percutaneous SI-screw fixation and augmentation over 15 years. Groups were compared concerning general epidemiological data, mobilization, complication rates, duration of stay, and safety of SI-screw insertion. Multivariable analyses were performed using logistic regression.

**Results:** Between 2005 and March 2020, 448 patients with 642 inserted SI-screws have been identified. Iatrogenic neurological impairment was documented in 2.5% of the cases and correlated with screw misplacement. Cement associated complications were observed in 22% of the cases. Out of these, spinal extravasation was detected in 3/118 cases (2.5%) and foraminal extravasation was seen in 2/118 cases (1.7%). In all patients, major and minor complications have been seen more frequent in males. Major complication rate in males (17.1%) was twice compared to females (8.8%) ( $p=0.0097$ ). Correct screw placement was accounted in 385 patients (91.2%), whereas minor screw displacement was found in 19 patients (4.5%) and major displacement was seen in 13 patients (3.1%). In 5 cases revision surgery was performed (1.2%). No reduction of screw-related complications using 3D navigation was seen ( $p=0.3076$ ) in our collective. Multivariable regression analysis revealed a reduced risk for major complications with augmentation versus none (OR 0.598).

**Discussion:** The present study included more than 640 percutaneous SI-screw fixations. It was shown that percutaneous SI-screw fixation is a safe and effective procedure for stabilization of the pelvic ring to the spine. A reduced risk for overall complications was seen in the augmented group as well as a shortened hospital stay, which may be explained by the better osseous retention. No significant differences between conventional SI-screw insertion and 3D-navigation was observed, which might be explained by an extended surgery time. Percutaneous SI-screw fixation is technically demanding and can be considered as a sufficient treatment method.

**References:** [1] König A, Oberkircher L, Beeres FJP, Babst R, Ruchholtz S, Link B-C. Cement augmentation of sacroiliac screws in fragility fractures of the pelvic ring-A synopsis and systematic review of the current literature. *Injury* 2019; 50(8): 1411–7 [<https://doi.org/10.1016/j.injury.2019.06.025>] [PMID: 31301810]

### V 35

#### Development and attrition of the intervertebral disc from the point of view of cellular spatial organization

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**Introduction:** To date, joint-preserving therapeutic approaches for degenerative disc disease aim primarily at controlling the symptoms and they do not restore the original disk structure or function. Great hopes are placed in the translation of cell-based therapeutic successes for treatment of articular cartilage defects to the intervertebral disk (IVD). To develop high-performing products a profound knowledge of the tissue architecture is essential. Our aim of the here presented study was to understand the cellular spatial architecture from the point of view of cellular organization from its earliest development until late stages of degeneration.

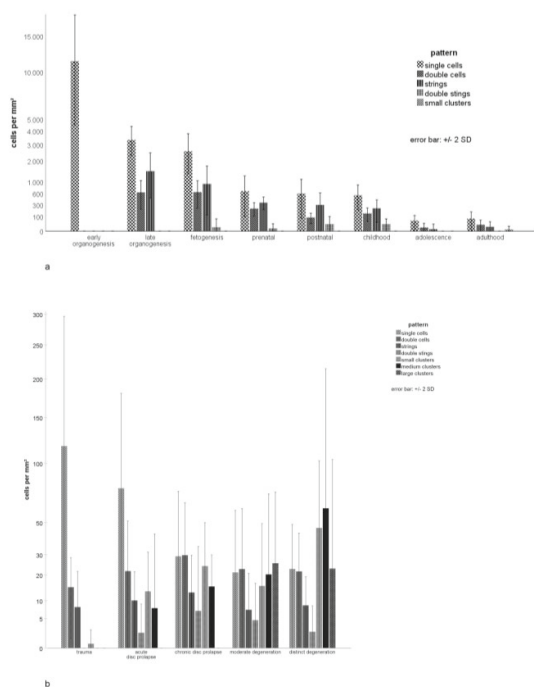
**Materials and Methods:** To investigate the physiological development, bovine IVD-material (anulus fibrosus) was divided in eight age groups ranging from early embryonic development to fully mature cattle. Tissue was immunohistochemically processed and its spatial cell organization was examined (n=72). Assessment of degenerative changes was carried out on human tissue which was obtained intraoperatively (n = 25). The human tissue was grouped and evaluated according to the patients' medical history, the tissue consistency as well as clinical and magnetic resonance imaging findings and it was finally divided in different stages of degeneration (trauma, IVD-prolapse, degeneration).

**Results:** An initially seemingly disordered tissue of high cell density in the early embryonic stage (11.435 cells per mm<sup>2</sup> in the histological section) quickly forms a higher-level cellular arrangement, which can already be distinguished in the process of organogenesis. Up to the first year of age, apart from single cells, mainly double cells and strings can be found. Through further development and ageing a significant decrease in cell density can be noted (min 71 cells per mm<sup>2</sup>) (p=0.03). Human traumatic tissue is similar to mature bovine IVD-tissue in terms of cell density and arrangement. With increasing degeneration, smaller and larger cell aggregates (clusters) appear, which are already established as a milestone in the development of osteoarthritis in human articular cartilage.

**Figure 1:** cells per mm<sup>2</sup> (anulus tissue) present in the different spatial patterns of bovine age groups (a) and human stages of degeneration (b)

**Discussion:** Similar to hyaline cartilage, spatial chondrocyte organization as well as the cellular density seem to act as image-based biomarkers for diagnosis and description of IVD-degeneration. This understanding of tissue-specific cell organization will be of great relevance, especially for the evaluation of experimental drug therapy approaches and the conception of specific regeneration matrices.

**Fig. 1**



## V 36

### Celecoxib for Discogenic Pain? An in vitro Study with Inflamed Human Intervertebral Disc Cells

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**Introduction:** The local expression of proinflammatory cytokines, such as tumor necrosis factor (TNF)- $\alpha$  and interleukin (IL)-1 $\beta$ , are associated with symptomatic intervertebral disc (IVD) degeneration (IDD). The IVD's proinflammatory microenvironment leads to an activation of nerve endings transmitting pain signals to the central nervous system. Brain-derived neurotrophic factor (BDNF) and nerve growth factor (NGF) are important markers on this mechanism and are related to discogenic pain. Thus, a possible approach for modulation of discopathy is to counteract the IVD's pro-inflammatory microenvironment. Inhibition of cyclooxygenase 2 (COX-2) by nonsteroidal anti-inflammatory drugs like celecoxib (CXB), showed promising effects in the last years. The present study sought to investigate the local effect of CXB on IVD cells in vitro. Specifically, we aimed to verify whether CXB has anti-inflammatory and anti-catabolic properties, and influences outgrowth and sensitization of adjacent nerve cells.

**Methods:** Human annulus fibrosus (AF) cells (N=2 donors) were harvested from patients undergoing spine surgery for traumatic disc injury. AF cells (in quadruplicates) were stimulated for one day with either TNF- $\alpha$  [10ng/ml] or IL-1 $\beta$  [10ng/ml] to induce inflammation. On day 2, CXB was supplemented to the AF cells at 1  $\mu$ M and 10  $\mu$ M, respectively. After 48h of stimulation, cells were collected and gene expression levels of matrix metalloproteinases-3 (MMP3), IL-6, IL-8, BDNF, NGF, and COX-2 were measured. Gene expression was normalized to cells on day 0. Unstimulated cells served as control. Furthermore, the conditioned medium of AF cells (N=1), was collected after 48h of stimulation and added to rodent dorsal root ganglion (DRG) neurons; 72 hours later, spontaneous and cytokine-induced pain signals following bradykinin supplementation were assessed by calcium imaging.

**Results:** Stimulation of AF cells with IL-1 $\beta$  or TNF- $\alpha$  upregulated the expression of MMP3, IL-6, IL-8, BDNF, NGF, and COX-2 compared to the control group. IL-1 $\beta$  showed a stronger inflammatory response in AF cells compared to the TNF- $\alpha$  group. In IL-1 $\beta$  stimulated AF cells, gene expression levels of BDNF were decreased by supplementation of CXB. MMP3 was downregulated by CXB in the TNF- $\alpha$  group but not in IL-1 $\beta$  stimulated AF cells. Spontaneous and cytokine-induced pain signals were elevated in the inflamed cells compared to the control group.

**Conclusion:** The outcome indicates an upregulation of inflammatory, neurotrophic, and catabolic markers in human AF cells cultured under proinflammatory conditions with TNF- $\alpha$ . CXB seems to reduce local cell catabolism and neovascularization of AF cells. CXB might have beneficial effects on discogenic pain as well as degenerative processes in the IVD. However future trials need to verify these indicative findings under more relevant conditions.

## V 37

### Can disc degeneration-associated factors activate terminal complement complex (TCC) formation?

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**Objective:** The formation of the terminal complement complex (TCC), a complement system activation product that acts as an inflammatory trigger and induces cell lysis, was identified in disc tissues from human patients and correlated with the degree of disc degeneration (DD)<sup>1</sup>. However, it is unclear which molecular factors play a role in complement activation during DD. Therefore, we investigated if degeneration associated factors can trigger TCC formation in disc tissue cultures.

**Methods:** Disc tissue biopsies were collected from adolescent idiopathic scoliosis (AIS, n=8, age 16±3) and DD (n=11, age 56±15) patients with ethical approval and informed consent. Standardized tissue punches from nucleus pulposus (NP), annulus fibrosus (AF) and endplate (EP) were separately cultured. Isolated cells were analyzed by flow cytometry and gene expression. Cells and tissues were stimulated with medium containing 5% human serum alone or supplemented with interleukin-1 $\beta$  (IL-1 $\beta$ , 10 ng/mL), cathepsin-D (0.5  $\mu$ g/mL) or zymosan (100  $\mu$ g/mL). Serum-free medium cultures were used as control. In cell cultures, TCC formation was determined by ELISA. In tissue cultures, TCC and CD59 formation were analyzed by immunohistochemistry. Statistics: Kruskal-Wallis in cell cultures, one-way ANOVA in explant cultures.

**Results:** In isolated cells, the deposition of TCC and expression of CD46, CD55 and CD59 significantly increased with culture (p<0.05). However, no differences were found in response to proinflammatory/degenerative stimuli, neither for AIS nor DD patients. In tissue cultures, compared to non-treated tissues, IL-1 $\beta$  stimulation led to lower percentage of TCC+ cells in AF and EP (p<0.05), whereas the presence of cathepsin-D significantly increased TCC formation in NP (p<0.01). The percentage of CD59+ cells significantly increased in AF and NP after stimulation with cathepsin-D and zymosan (p<0.05).

**Conclusion:** These data suggest that complement activation and TCC formation can be induced in vitro if disc cells are kept in their native tissue environment. Interestingly, the presence of IL-1 $\beta$ , a pro-inflammatory molecule, led to less TCC formation in AF and EP. TCC deposition seems to be a degeneration-associated event and IL-1 $\beta$  was shown to influence cell lysis or TCC sublytic effects possibly via a negative feedback mechanism. Nevertheless, TCC formation was shown to be triggered by cathepsin-D, a C5 cleaving protease with an important role in osteoarthritis, but poorly described in DD regarding complement activation. Overall, these results suggest a functional relevance of IL-1 $\beta$  and cathepsin-D in modulating TCC formation. Ongoing mechanistic studies investigate the potential of TCC as a new target for DD therapy.

**References:** 1. Teixeira et al., DWG, 2019.

### V 38

#### MSC secretome decreases pro-inflammatory response in loaded AF organ cultures

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**Objective:** Failure of the annulus fibrosus (AF) is often associated with disc herniation and activation of an immune response. Mesenchymal stem/stromal cells (MSC)-based therapies have been proposed for back pain and disc degeneration, despite limited knowledge on their action mechanism. Hence, we investigated the impact of a cell-free therapeutic approach with MSC secretome on AF organ cultures (AF-OCs) exposed to mechanical overload in a proinflammatory environment.

**Material/Methods:** In the AF organ culture model<sup>1</sup>, 6 parallel AF rings punched from bovine intervertebral discs were stimulated with high-physiological cyclic tensile strain (CTS, 9%, 1Hz, 3h/day for 4 or 9 days) and IL-1 $\beta$  (10 ng/mL) medium supplementation. A sub-group of stimulated AF-OCs was treated

with human MSC secretome produced by pre-conditioned MSC (10 ng/mL IL-1 $\beta$ , 6% O<sub>2</sub>, 8.5% CO<sub>2</sub> for 48h). Unstimulated AF-OCs served as control group. Bovine AF cells' gene expression was evaluated by real-time PCR. IL-6 and MMP3 production were evaluated by immunohistochemistry. Collagen tissue content was quantified by biochemical assay and the AF adhesive strength by peel-test as described<sup>1</sup>. Statistics: Kruskal-Wallis test.

**Results:** Four days after stimulation/treatment, the bovine inflammation markers IL-6, IL-8, complement regulator CD46, and matrix degrading enzymes MMP1, MMP3 and ADAMTS4 were upregulated in CTS+IL-1 $\beta$  compared to unstimulated AF control group (P<0.05), whereas matrix components COL1A1 and ACAN, metalloproteinase inhibitors TIMP1 and TIMP2, neovascularization marker VEGF, and complement regulators CD55 and CD59 were not altered. IL-6, IL-8, MMP1, MMP3, ADAMTS4, COL1A1, TIMP1, TIMP2, CD46, CD55 and CD59 were downregulated by the MSC secretome versus CTS+IL-1 $\beta$  (P<0.05). At the protein level, it was confirmed that IL-6 and MMP3 staining intensity decreased after MSC secretome treatment of the CTS+IL-1 $\beta$  group (P<0.05). AF collagen content (at day 4) and adhesive strength (at day 9) were also decreased by the MSC secretome treatment (P<0.05).

**Conclusion:** AF cells presented a pro-inflammatory/degenerative phenotype after CTS+IL-1 $\beta$  stimulation for 4 days. But, the previously described matrix weakening effect of the CTS+IL-1 $\beta$  stimulation<sup>1</sup> did not correlate with changes in the tissue's collagen content. Interestingly, the MSC secretome contributed to a decrease of the inflammatory and catabolic status of AF cells activated by CTS+IL-1 $\beta$ , and to play a role in the regulation of the complement system. However, it also contributed to a further decrease of collagen at gene/protein level and of the AF mechanical strength. Therefore, the use of MSC secretome as therapeutic approach for disc-related diseases requires further mechanistic investigations before clinical trials.

**References:** 1. Saggese et al, 2019.

**Acknowledgement:** Ulm University (LSBN0157), DWG, Humboldt Fnd.

### V 39

#### Sonic hedgehog improves survival and differentiation of transplanted neural precursors cells and modulates secondary injury processes after thoracic spinal cord injury

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**Introduction:** Neural precursor cell (NPC) transplantation has shown beneficial effects on neuroregeneration after SCI. However, the survival and differentiation of transplanted NPCs remain limited. The Sonic Hedgehog (SHH) pathway is involved in embryogenesis but might act on adult NPCs as well, playing a protective role after CNS injury. We, therefore, investigated the effects of intrathecal SHH administration on transplanted NPCs as well as the impact of this combined treatment approach on secondary injury processes and functional recovery after thoracic SCI in rats.

**Methods:** 37 Wistar rats were subjected to severe thoracic clip-contusion/compression SCI at T10. Animals were randomized into five treatment groups (SHH only, NPC only, SHH+NPC, Vehicle, Sham). One week after SCI, NPCs were injected into the spinal cord of the immunosuppressed animals and osmotic pumps for 7-day continuous intrathecal Shh/Vehicle-administration were implanted. Basso, Beattie and Bresnahan (BBB) score, Gridwalk test, and CatWalk gait analysis were weekly performed to assess functional recovery. Animals were sacrificed 6 weeks after SCI and immunohistological analyses were conducted. Results were compared between groups and statistical analysis was performed (p < 0.05 was considered significant).

**Results:** With the administration of SHH, the survival of transplanted NPCs as well as their differentiation into adult neurons and oligodendrocytes was significantly increased 6 weeks

after SCI. While the administration of SHH alone had significantly attenuated the inflammatory response (T-lymphocytic invasion, macrophagic infiltration, and polarization) and significantly reduced the resident microglia as well as reactive astrogliosis, the impact of NPC-transplantation alone on such postinjury processes was limited. However, when SHH-administration and NPC-transplantation were combined, neuroinflammation as well as microglial activation, apoptosis, astrogliosis, and cyst formation were further improved. Finally, only the combined treatment approach led to significant improvements in functional recovery 6 weeks after severe thoracic SCI.

**Conclusion:** In our study, a combined treatment approach with intrathecal SHH-administration and NPC-transplantation showed the highest improvements of neuroregeneration on the cellular as well as the functional level 6 weeks after severe thoracic SCI. SHH might, therefore, be a potential candidate for the enhancement of stem cell transplantation in the treatment of SCI.

#### V 40

##### The work situation of spine surgeons in German-speaking countries: Results of a Cross-sectional Study

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**Background:** The growing number of patients, complications and lack of time are only a few factors that physicians have to cope with every day. In this study, we sought to investigate the work situation and level of distress in spine surgeons in German speaking countries.

**Methods:** We conducted an online survey of spinal surgeons practicing in German-speaking countries (Germany, Austria, Switzerland) using the Survey Monkey platform. An invitation to participate was sent to the members of German Neurosurgical Society (DGNC) and the German Spine Society (DWG). The quality of life (SF-8), substance abuse, mental health (GHQ-12), perceived stress (PSS-4) and resilience (BRS) were evaluated. Information about work situation and demographics were collected.

**Results:** In total, 546 surgeons responded to the survey. Mental distress among spinal surgeons was higher than in the general population ( $M=11.0$  ( $SD=5.2$ ) vs.  $9.7$  ( $SD=4.5$ )). Moreover, perceived stress was higher among the respondents ( $M=11.00$  ( $SD=5.22$ ) vs.  $M=9.70$  ( $SD=4.49$ )). The highest level of perceived stress was among residents ( $M=10.0$  ( $SD=2.5$ )) and the lowest among chief surgeons ( $M=8.3$  ( $SD=8.3$ )). The same trend was observed in the levels of mental distress ( $M=13.0$  ( $SD=5.4$ ) and  $9.4$  ( $SD=4.2$ )). Spinal surgeons appear to recuperate better from stressful situations ( $M=3.75$  ( $SD=0.71$ ) vs.  $M=3.35$ , ( $SD=0.95$ )). There was a positive correlation between perceived stress and mental distress ( $r=0.679$ ,  $p=0.01$ ).

**Conclusions:** Spinal surgeons report higher levels of perceived stress, which translates into higher level of mental distress which decreases with growing experience. Spinal surgeons appear to recuperate better from stressful situations than the general population.

#### V 41

##### Individuals at risk for back and neck pain – results of an occupational health screening in 27492 employees

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**Introduction:** Back and neck pain are major economic factors in a workplace environment responsible for 15–30% of all days of sick leave in Germany. Our study aims to identify factors responsible for increased back and neck pain in order to establish a screening tool and a specific intervention program for individuals at risk for spinal morbidities.

**Methods:** The study was set as a voluntary occupational health screening. Companies had 500 to >5000 employees. Participants completed a survey on spinal conditions, pain and a 5-question depression inventory and were examined by a licensed physician in a standardized procedure. Data was anonymized and statistics were computed using SPSS v26.

**Results:** Overall 27492 employees were included. 41.5% were female and median age was 43. Most common industrial sectors were manufacturing industries (43.4%), and insurance companies (24.6%). Relevant neck and lower back pain was reported by 24.8% and 31.4% of all individuals and was significantly influenced by workplace variables such as workload ( $p<0.001$ ), posture at workstation ( $p<0.001$ ) and industrial sectors (authorities>traffic>service>insurances,  $p<0.001$ ). We found a strong correlation (Spearman  $\rho$  0.374–0.416,  $p<0.001$ ) of depression and stress screening items with self-rated work absence. Individuals suspected for depression reported to be absent from work "often" or "always" in 64.6–78.6% compared to 20.6–39.5% of individuals without signs of depression ( $p<0.001$ ). Individuals reporting to be absent from work "often" or "always" had a high prevalence of neck pain 43.9–46.9% compared to those who were "never" or "rarely" absent 11.1–20.2% ( $p<0.001$ ) as well as back pain 52.0–56.0% vs. 13.8–26.2% ( $p<0.001$ ). A significant decrease in prevalence of neck pain was identified for endurance activities with reduced neck pain levels compared to the study population (21.8% vs. 27.9%,  $p<0.001$ , OR 0.72). Similar results were observed for contact sports (16.8% vs. 25.8%,  $p<0.001$ , OR 0.58), Golf/Tennis (20.9% vs. 25.0%,  $p<0.01$ , OR 0.79) and martial arts (22.8% vs. 24.9%,  $p=0.22$ , OR 0.89). Back pain was reduced in clients participating in endurance sports (27.5% vs. 35.2%,  $p<0.001$ , OR 0.70) and contact sports (25.5% vs. 32.1%,  $p<0.001$ , OR 0.73), as well as Tennis/Golf (27.1% vs. 31.6%,  $p<0.001$ , OR 0.80) and martial arts (29.3% vs. 31.4%,  $p=0.24$ , OR 0.91).

**Discussion:** Our study demonstrates the overall high prevalence of back and neck pain in a workplace environment. We were able to identify numerous factors affecting the prevalence of back and neck pain. Thus, our analysis provides the basis to identify individuals at risk for spinal morbidities and develop specific workplace related interventions to decrease absences from work due to neck and back pain.

#### V 42

##### An increase in work capacity at 5 years following an multimodal rehabilitation model in low back pain

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**Introduction:** In chronic low back pain, the most expensive patients are them with long-standing sick-leave of more than 6 months. It is known that multidisciplinary rehabilitation models could be successful. Over short-time the results are encouraging but which are the results at 5 years?

**Purpose/Aim:** The aim of this study was to analyze the impact of a multidisciplinary rehabilitation program for chronic lumbar pain associating occupational strategies and an approach of kinesiophobia on work capacity on follow-up at 5 years. Secondary outcomes were pain evolution and apprehension of movement and work

**Materials and Methods:** We have done a retrospective analysis of 450 of our patients 5 years after that they have followed a multidisciplinary program. The program contained physical training, occupational tasks developed on the basis of the fear-avoidance model of Waddell.

We have analyzed the evolution of work capacity, the apprehension according to different questionnaires (FABQ, Tampa scale (TSK) and PACT (evaluating the subjective work capacity)), at beginning of the program, at 1 and 5 years.

**Results:** We saw a clear increase in the global work capacity at one year: passing from 41 to 79% ( $p<0.01$ ) which was maintained at 5 years at 75% ( $p<0.01$ ). In parallel there was an increase in the subjective sensation of physical capacity (Pact) 79 up to 136/200. This increase was correlated with a decrease in fear-avoidance according to the Fabq, and in the TSK: which were almost stable at

5 years, with a little decrease in the daily activity apprehension 39 down to 36/68.

**Conclusion:** In chronic low back, a multidisciplinary rehabilitation program, gives a global work capacity of 79% at one year, almost stable at 5 years. This capacity is stable since we are focalising on patient's apprehensions with gradual exposure according the fear-avoidance model developed by Waddell and explored by Vlayen. An increase in body confidence rests the important factor in these functional restoration programs.

**Reference(s):** Waddell G et al. Low back pain, fear-avoidance beliefs and disability: With the development of a Fear-Avoidance Beliefs (FAB) questionnaire. *Pain* 1993;52:157-68

Vlaeyen JWS et al. Graded exposure in vivo in the treatment of pain-related fear: a replicated single-case experimental design in four patients with chronic low back pain. *Behaviour Res Therapy* 2001;39(2):151–66

#### V 43

##### **Different approaches to artificial intelligence for analysis of the therapy efficiency of 1000 conservatively treated spine patients – towards explainable AI**

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**Introduction:** The efficiency of conservative spine therapy depends on the causes and characteristics of the complaints and the results are difficult to predict. In a translational study, approaches to establish artificial intelligence were applied comparatively to analyse conservative spine treatment in 1000 patients.

##### **Methods/Material:**

1000 conservatively treated stationary patients in a spine centre were investigated. Basic data, ODI, and VAS values were collected at admission and discharge and processed by the pandas python package (pandas v. 0.23.1; python 3.6.7). Correlation matrix (matplotlib v. 2.1.2 and seaborn v.0.8.1), density distributions, histograms and basic statistical analyses were performed with the data set.

We followed two different approaches:

1. Supervised AI predicting the ODI score at discharge as a target predictive value. The machine learning problem was a linear regression problem. Parameters were analysed and partly dropped to reduce complexity (feature selector v.1.0.0). A neural net was built using categorical and continuous variables implementation via separate input layers. The Keras framework (v. 2.2.4) with tensorflow backend (v.1.12.0) was used to model the network architecture and perform network training.
2. Unsupervised AI to visualize our data. We used a Python implementation of a Uniform Manifold Approximation and Projection for Dimension Reduction (UMAP) algorithm and the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) to identify 8 clusters in our data. These clusters were marked and then a simple neural network was trained to predict these cluster markings. Next, we identified the characteristics that define the clusters using the Python implementation of shapley additive explanations (SHAP), which provides a game-theoretic approach to explain the output of any machine learning model. Finally, we were able to understand which data components cause clustering.

**Results:** The 10-fold cross-validated model of the supervised AI achieved a mean absolute error of 11.4% in the ODI prediction. The non-supervised AI model identified 8 clusters. Training of a supervised model to learn the assigned cluster markers achieved an accuracy of 97% in 10-fold cross-validation. After visualization, it

was found that the cluster formations are caused by specific groups of ICD-10 codes.

**Discussion:** This project shows how different approaches to artificial intelligence can be applied individually and in combination in a patient collective. By specific training of a supervised AI to predict the formation of non-supervised clusters, a precise definition of the underlying parameters is possible. Thus, not only a prediction of the conservative therapy efficiency is possible. The knowledge of the cluster composition allows an assignment of patients to a pathology solely by the initial scores and baseline data.

#### V 44

##### **Radiofrequency denervation therapy for lumbar facet joint arthropathy: enhanced outcome compared with chemical neurolysis (Ethyl Alcohol 95% or Glycerol 20%)**

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**Introduction:** Chronic low back pain is a major source of disability and loss work productivity worldwide. Treatment modalities of back pain due to facet joint arthropathy include chemical neurolysis (Ethyl Alcohol or Glycerol) and radiofrequency denervation of lumbar facet joints. Long-term outcome of these semi invasive techniques, however, are currently unclear. We hypothesize that radiofrequency denervation is associated with superior pain abolishment and less complications than chemical neurolysis.

**Methods:** For this prospective follow-up study we enrolled patients between 01.12.2017 and 01.12.2019. Adult patients with recurrent chronic low back pain, resistant to non-invasive therapy and steroids injections were included. Spinal imaging was performed to exclude alternative diagnoses. Patients were grouped based on treatment modality. The following groups were compared: radiofrequency denervation (Gr. RFD), chemical neurolysis with Ethyl-Alcohol 95% (Gr. EA-95) or Glycerol 20% (Gr. Gly-20). The Core Outcome Measures Index for the back (COMI), World Health Organisation (WHO) pain ladder level and VAS (Visual Analog Scale)-scores were determined. Furthermore, complications were documented and compared between groups. Outcome was determined pre-interventional, after 6 weeks, 6 and 12 months.

**Results:** A total of 95 patients (60 female and 35 male) with a mean age of 63.7 years were included. Prior to intervention, a mean COMI-score of 8.31 and a VAS-score of 8.01 were encountered. A total of 30 patients underwent RFD, 35 patients were treated with EA-95 and 35 patients were exposed to Glycerol 20% neurolysis. Subjects were on an average WHO-pain ladder level of 1.39. No statistically significant differences were found between the three groups. Upon intervention however, patients treated by RFD had significantly lower VAS-levels compared with Ethyl Alcohol after 6 weeks (VAS: 4.33 vs.6,12 (P<0.05)). Furthermore, after 6 months both VAS and COMI-scores were significantly decreased in RFD-patients than those treated by Gly-20 (respectively VAS:4.42 vs.6.64, P<0.01 and COMI: 5.08 vs.7.43, P<0.01). After 12 months, VAS-scores were significantly lower in Gr. RFD vs Gr. Gly-20 (4.72vs.7.44,P<0.05), whereas complications rates were higher in patients treated by EA-95 than by RFD and Gly-20 (30% vs.6.7% and 2,9%, P<0.05).

**Conclusion:** This prospective follow-up study is the first to show that in patients with recurrent chronic lower back pain, radiofrequency denervation therapy is associated with improved pain-relief and quality of life compared with alternative modalities of chemical neurolysis. Furthermore, more complications are seen in patients treated by chemical neurolysis by Ethyl Alcohol 95% than other treatment options. In our view, in the absence of contraindications (such as a pacemaker/cochlear implants) radiofrequency denervation should be considered as the treatment of choice in patients with symptomatic facet arthropathy.

## V 45

**The clinical results after infiltration therapy in degenerative changes of the lumbar spine and operation rate after three years – a patient evaluation of two centers**\*K. Kafchitsas<sup>1</sup>, P. Drees<sup>2</sup>, S. Matyasovszky<sup>2</sup><sup>1</sup>Asklepios Klinik Lindenlohe, Wirbelsäulenzentrum, Schwandorf, Germany<sup>2</sup>Universitätsmedizin Mainz, Mainz, Germany

**Aim:** Changes in the functionality and pain in patients with degenerative changes of the lumbar spine after infiltration therapy and the influence of infiltrations on their quality of life. The percentage of patients who were operated after three years was also evaluated.

**Material and Method:** 1053 consecutive patients have received first conservative treatment for low back pain during 2014–2017. Repetition of conservative treatment in our or other hospital until 2020 was also evaluated. Before and after admission modified versions of Short-Form-36 (SF-36) and Oswestry Disability Index (ODI) have been performed. Only questionnaires filled in at least two months after hospitalisation were taken into consideration. Patients were treated because of low back pain with facet joint injections (FIs) and peridural anaesthesia (PDA) depending on the MRI findings and symptoms. During hospitalisation no intravenous analgesics were administered. FIs with corticosteroids were administered only if injections without corticosteroids resulted in temporary pain relief. Additionally, a psychological assessment of the patient was carried out. Statistical analysis was performed by means of Sigmaplot 12.0. Common indications were facet joint arthritis, spinal canal stenosis and post-nucleotomy syndrom.

**Results:** Mean age was  $58 \pm 12$  years (max. 81 y. and min. 18 y.). Post treatment, there was a significant improvement of the ODI ( $p=0.009$ ). The evaluation of the SF-36 showed significant improvement in the sections of physical functioning ( $p=0.012$ ), physical role functioning ( $p=0.014$ ), bodily pain ( $p<0.001$ ), social role functioning ( $p=0.016$ ) and emotional role functioning ( $p=0.008$ ). With  $p<0.001$  a statistically significant change occurred in all 8 SF 36 questionnaire scans. The Oswestry questionnaire evaluation showed an average of 44, 1% (SD: 14.6) and 33.7% (SD: 15.1) in the pre- and post-invasive groups respectively, with  $p<0.001$ . 35% of the patients treated had at least one repetition of the conservative treatment in the first three years after first treatment. 13% were operated after first treatment and another 13% after more than one repetitions.

**Discussion:** The evaluation of the Oswestry Disability Index, which measures functional impairment, showed a statistically significant improvement of pain level and quality of life. Thanks to this, the limitation of patients improved from "severe" to "moderate" according to the definition. The evaluation of the SF-36 also showed a significant postinterventional improvement in all scales of the questionnaire. Patients were able to benefit from infiltration therapy both in terms of physical health and mental condition. There was also a good correlation between the two questionnaires. Despite the diminishing effect of conservative pain management, the treating physician succeeds in correlating clinical and radiological findings. This also facilitates the establishment of a possible operative regime.

## V 46

**Isokinetic trunk strength data in young elite and senior elite athletes: relation to back pain incidence**\*P. Flöbel<sup>1</sup>, K. D. Schaser<sup>1</sup>, A. C. Disch<sup>1</sup><sup>1</sup>Universitätsklinikum Carl Gustav Carus an der Technischen Universität Dresden, UniversitätsCentrum für Orthopädie & Unfallchirurgie, University Comprehensive Spine Center, Abteilung für Sportmedizin und Prävention, Dresden, Germany

**Background:** Among German athletes, back pain (BP) is often a cause for missed training and competition time. Sports specific prevalences up to 77 % in adults and 23 % in young athletes were shown. The compensation of sport-associated loads largely depends on trunk strength (TS) capacity. Failure is mainly associated to an insufficient TS and simultaneously altered trunk

strength leading to an imbalance. The relationship between back flexors and extensors thereby provides an explanatory model for this imbalance resulting in BP. Isokinetic measurement is often used for the diagnosis of TS. The aim of this study is the analysis of age- and discipline-specific TS data of German young- and senior-athletes and their comparison with the occurrence of BP in this population.

**Methods:** The prospective analysis included 195 athletes from 9 sport disciplines who were investigated between 2019/20 in a DOSB-licensed department for sports medicine. The qualitative BP survey was carried out by means of the Korff pain questionnaire. The maximum Rk was recorded concentrically over 10 repetitions at 60°/s using a dynamometer (Ferstl GmbH, Hemau, Ger). The data description is based on the absolute flexion torque, standardised to the body weight (Flexabs / Kg = Flexnorm) as well as the extension (Extabs / Kg = Extnorm) and the quotients (Rkquot = Flexabs / Extabs), indicated as median and 0.25/ 0.75 quartile. Group comparisons were made by the Mann-Whitney U-Test. A  $p$ -value  $\leq 0.05$  is considered significant.

**Results:** Over all subjects; gender=88/107 F/M; age=16.8[15.2; 18.9]y; body height=178[170; 183]cm, weight=66.8[57.2; 76.4]kg, BMI 21.1 [19.6; 23.2], 42 % of the athletes stated that they had been affected by BP at least once during the last three months. Female athletes were significantly more often affected (46 % vs. 36 % F/M). The frequency, intensity and impairment of pain did vary between the disciplines. BP-athletes presented with a different pattern of TS values in relation to non BP-athletes in the same sports discipline (RKquot reached 0.60 vs. 0.53, BP/non BP, ( $p\leq 0.05$ )). For the total cohort ( $n=195$ ) the TS values were Flexnorm 2.2 [1.9;2.3], Extnorm 4.3 [3.7;4.7] and a Rkquot of 0.50 [0.46;0.58]. With comparable age, gender and pain structure, the Rkquot varied depending on the discipline between 0.53- 0.66, ( $p\leq 0.05$ ).

**Conclusion:** There is an age, gender and discipline specific prevalence of BP episodes in this population. BP-athletes had partially an increased RKquot due to a reduced extension strength compared to flexion strength. The RKquot shows sport-specific adaptation of the TS. Sports-specific characteristics of TS seem to have a key role to predict the BP risk in athletes.

The achieved data could be the basis for an individual, preventive risk assessment, for the indication and validation of TS intervention programmes. Further longitudinal studies are necessary to clarify these questions.

## V 47

**Corpectomy for treatment of syringomyelia for patients with complete paraplegia**\*J. Klekamp<sup>1</sup><sup>1</sup>Christliches Krankenhaus, Neurochirurgie, Quakenbrück, Germany

**Introduction:** Corpectomy has been a therapeutic option for patients with complete paraplegia and ascending, symptomatic syringomyelia for more than 50 years but receives little attention nowadays.

**Material/Methods:** 20 patients with complete paraplegia and ascending syringomyelia underwent corpectomies between 2007 and 2020 (15 males, 5 females; 18 posttraumatic, one patient each following listeria meningitis and intradural tumor surgery, respectively; age:  $49\pm 10$  years) and were entered into a database continuously. The cord was exposed at the level of the complete lesion, transected and the cranial part dissected free of any adhesions with the surrounding dura. The dura was closed with a duraplasty and laminae reinserted. Postoperatively, patients were followed clinically and with MRI before discharge, after 3 months and yearly thereafter.

**Results:** All patients presented with ascending neurology, three with symptomatic syringobulbia. The interval between trauma and new syrinx related symptoms was extremely variable (5 months to 40 years, mean:  $129\pm 143$  months), before another  $32\pm 57$  months passed by until presentation. Symptoms started with distal upper extremity weakness in 11 patients, neuropathic pain in 6 and sensory deficits in 3 patients. The level of corpectomy was as high as C6 in 3 patients, at Th1 in 2 patients and between Th3 and Th10

in the remainder. For 9 patients corpectomy was the primary treatment of syringomyelia, while the remaining 11 patients had undergone up to 7 unsuccessful syrinx operations before finally undergoing corpectomy (complications: 1 infection, 3 CSF fistulas).

14 patients experienced neurological improvements of their upper extremity functions, while neurological progress was stopped in 6 patients. Improvements were noted for motor function in 6, sensory functions in 5, dysesthesias in 4 and pain in 4 patients. No patient developed a new or an aggravated neurological deficit. In each patient the syrinx collapsed and did not reappear during follow-up. Discussion: Corpectomy is by far the most efficient therapy of syringomyelia and should be offered to patients with complete paraplegia as a result of trauma or other underlying diseases, if the syrinx ascends from that spinal level. Even after multiple unsuccessful attempts to treat such a syrinx corpectomy will lead to a persistent collapse of the syrinx and prevent ascending neurological deficits.

#### V 48

##### The challenge of spine surgery initial treatment of a cervical spine injury with acute traumatic spinal cord injury – an analysis of risk factors, outcome and survival

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**Introduction:** Due to the emergency situation and the severity of the injury, traumatic cervical spine injuries with spinal cord injury represent a surgical challenge for the primary care center with the corresponding infrastructure and number of spinal surgeons. The few literature references show a high surgical and treatment-relevant complication rate for these injuries (Wilson JR et al., 2012, Bourassa-Moreau É et al 2013). The aim of the study is to analyse risk factors, outcome and survival.

**Methods:** The study was conducted from 2011 to 2017 (Ethics Committee EA2/015/15). Medical (Register Comparative Outcome- and Treatment-Evaluation in Spinal Cord Injury) and health economic data (Institute for the payment system in hospitals) were analysed. The analyses were carried out in the overall group and in a propensity score matched group (age, sex, BMI, ASIA Impairment Scale (AIS), Charlson comorbidity index). Risk factors for the endpoints complications, outcome and death were examined in adjusted statistical models.

**Results:** In the total group 168 patients were analyzed and in the matched group 85 patients. The outcome "AIS conversion by one value" showed a significant association for the absence of AIS conversion in case of complete spinal cord injury (AIS A) ( $p=0.006$ ) and in case of spinal surgical adverse events (SSAE) ( $p=0.006$ ). SSAE were associated with significantly more lung infections (69% vs. 48%;  $p=0.027$ ) and decubitus (49% vs. 27%;  $p=0.018$ ). Primary AIS A ( $p=0.049$ ) and SSAE ( $p=0.009$ ; 20.6% vs. 6.3%) were associated with permanent dysphagia with tracheal cannulation. SSAE occurred in 23% of the total group, with mechanical instability (8.3%), insufficient spinal decompression (6.5%) and osteosynthesis malposition (4.2%) being the most common. SSAE led to an extended treatment time and costs (Table 1). SSAE resulted in a significantly higher mortality rate (Figure 1). The analysis of the factors time of surgery and DWG certificate showed no significant difference in the number of SSAE during day or night time. However, spinal surgeons with DWG certification had significantly

( $p<0.001$ ) less SSAE (7%) than those without DWG certification (37%).

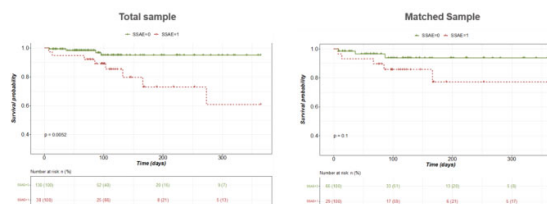
**Conclusion:** Spinal surgical complications and primary AIS A are an independent risk factor in the initial management of traumatic cervical spine injuries with spinal cord injury with implications for the neurological and functional outcome and for health care costs. Due to the spinal surgical and cross-sectional challenges, primary care should be reserved for centers with sufficient care services and certified spinal surgeons.

**Fig. 1**

Length of stay and treatment costs					
Total sample					
Treatment duration	Group without SSAE	n	Group with SSAE	n	p-value
Length of stay in d, Median (IQR)	72.6 (34.8-116.5)	91	101.3 (86.2-120.6)	18	0.008
Variable	Group without SSAE	n	Group with SSAE	n	p-value
Surgery costs in €*1000, Median (IQR)	4.6 (2.6-6.8)	91	7.6 (5-9.9)	17	0.001
Intensive care unit costs in €*1000, Median (IQR)	4.5 (0.8-27.6)	88	29.1 (3.6-44.2)	18	0.006
Total treatment costs in €*1000, Median (IQR)	52.3 (26.7-91.2)	91	97.3 (78.2-112.3)	18	0.001
Matched sample					
Treatment duration	Group without SSAE	n	Group with SSAE	n	p-value
Length of stay in d, Median (IQR)	72.7 (34.8-129.9)	44	104.4 (86.2-120.6)	14	0.132
Variable	Group without SSAE	n	Group with SSAE	n	p-value
Surgery costs in €*1000, Median (IQR)	5.6 (2.6-7.6)	44	7.7 (4.9-9.8)	14	0.031
Intensive care unit costs in €*1000, Median (IQR)	11.3 (0.8-34.7)	42	31.9 (16.6-57.2)	14	0.041
Total treatment costs in €*1000, Median (IQR)	58.4 (24.0-116.9)	44	93.4 (78.2-115.9)	14	0.037

Values in bold typeface represent statistically significant p-values.  
SSAE, spinal surgery adverse events; IQR, interquartile range.  
Excluded: cases of the statutory accident insurance, patients who received the first surgery in another center and patients who died during primary care.

**Fig. 2**



#### V 49

##### Unilateral approaches for posterior spinal canal decompression in cervical spondylotic myelopathy

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**Introduction:** Laminectomy and -plasty are standard posterior approaches for operative treatment in patients with cervical spondylotic myelopathy (CSM). However, both techniques have procedure-related disadvantages, which might be avoided by unilateral posterior approaches followed by bilateral decompression of the spinal cord. To elucidate this hypothesis, we compared the outcome after two different unilateral approaches with that after a bilateral posterior approach to the spine for bilateral decompression in CSM patients.

**Material/Methods:** Medical records of 98 patients undergoing posterior cervical surgery due to CSM between 2012–2018 were assessed. Patients were divided into three groups by surgical procedure: i) a unilateral interlaminar fenestration with over-the-top undercutting (laminotomy) for compression limited to a hypertrophy of the ligamentum flavum, ii) a unilateral hemilaminectomy for lateralized compression with a combination of ligamentous hypertrophy and osseous stenosis, and iii) laminectomy/-plasty for circular osseous-ligamentous spinal canal narrowing. Clinical characteristics, operative records, complications, and imaging findings as well as individual outcomes with regard to myelopathic symptoms (Japanese Orthopedic Association score, mJOA), axial neck pain (Visual analogue scale, VAS), quality-of-life aspects (QOL: Short Form-36v2® Health Survey, SF-36; Neck Disability Index, NDI), and general performance in daily life (Barthel Index, BI) were analyzed and compared.

**Results:** Mean age was 73 years with a slight predominance of the male sex (m:f=1.4:1). The most frequent symptoms (mean duration: 15 months) were ataxia (69%) and sensory changes (57%). Main location of stenoses (median Naganawa-Score: 3; mean AP spinal canal diameter: 7.7±2.2 mm) were the C3- to C6-level. 31% of the patients (30/98) were eligible and assigned for a laminotomy procedure, 20% (20/98) for a hemilaminectomy and 49% of the patients (48/98) for a laminectomy/laminoplasty. There were no significant differences of patients' characteristics, blood loss, operation time and in-patient stay between the three surgical groups. Independent from the mode of surgery, the spinal canal was significantly widened (median Naganawa-Score: 0; mean AP diameter: 11.4±3.6 mm) and myelopathy (mJOA-Score) improved (each  $p<0.001$ ). QOL (SF-36/NDI) was similar in the three surgical groups at last follow-up (mean: 28 months), while reduction of neck-pain level was most pronounced in the least-invasive laminotomy group.

**Discussion:** Individual tailoring of the surgical approach according to the underlying compressive pathology is feasible in CSM in order to achieve the minimal periprocedural burden for the patients. If applicable, unilateral approaches enable a satisfying neurological and QOL outcome during long-term follow-up.

## V 50

### Degenerative cervical myelopathy: Quantitative analysis of MR spectroscopy via segmentation of gray and white matter in the primary motor cortex to evaluate ongoing pathomechanisms

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**Introduction:** The exact pathophysiological mechanism in the primary motor cortex of patients with degenerative cervical myelopathy (DCM) are still unclear. The aim of the present study was to detect pre- and postoperative alterations of crucial neuro-metabolites in the primary motor cortex of patients with DCM using MR spectroscopy (MRS). Specifically, and to establish a precise method of measurement, alterations were inspected in gray (GM) and white matter (WM), respectively, while excluding/controlling for cerebral spinal fluid (CSF) for partial volume effects.

**Methods:** MR spectroscopy was performed in 38 DCM patients (mean age 61.3±11.4; male n=24 and female n=14) with consistent imaging findings and indication for surgical decompression before, and additionally, in 20 patients six months after surgery. 20 healthy and age matched volunteers served as control group (CG) (mean Age 63.7±6.3; male n=11 and female n=9). The neurological status and clinical scores (mJOA, NDI) of patients and volunteers were collected. MRI and MRS were performed at a 3T scanner with following sequences for the brain: 3D-T1 (MPRAGE), fMRI with a finger tap paradigm for spectroscopy voxel positioning at the primary motor cortex. MR spectroscopy assessing: Creatinine (Cr), N-acetyl-aspartate (NAA), Choline (Cho), and Inositol (Ins). After co-registration to the structural image, the spectroscopy voxel was classified into grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF) using Matlab and

SPM12. Metabolite concentrations were corrected for CSF-partial volume effects and additionally analyzed accounting for GM- and WM-fractions.

**Results:** DCM and controls differed significantly concerning the clinical status (mean mJOA: DCM 11.2±3.2; CG 18±0,  $p<0.001$ ; NDI: DCM 40.7±23; CG 4±6.5,  $p<0.001$ ). Measurements corrected for CSF revealed significant concentrations of NAA between patients and CG (mean NAA DCM: 120.0±23.2; CG 135.7±16.5,  $p=0.012$ ). In the analyses of pre- and postoperative patients, metabolites presented significant differences 6 months after surgery especially in the gray matter of the primary motor cortex (mean Cr: preop 203.3±75 vs. postop 166.8±52.4,  $p<0.05$ ; mean Ins: preop 141.1±62.8 vs. postop 114.7±39.9,  $p<0.05$ ; mean Cho: preop 113.4±43.2 vs. postop 97.6±31.6,  $p<0.05$ ).

**Conclusion:** Decreased NAA in the primary motor cortex presents an impairment of neuronal function, mitochondrial dysfunction and neuronal density in DCM patients. Postoperatively, metabolites for reactive gliosis/neuroinflammation (Ins) are decreased. Reduced cellular turnover (Cho) and metabolic activity (Cr) seems to be an ongoing pathomechanism in the primary cortex even after decompressive surgery.

## V 51

### Is it possible to provoke cervical disc herniations in vitro?

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**Introduction:** Although 36% of all spinal diseases affect the cervical spine [1], much less is known about cervical herniated discs than about lumbar herniated discs. Many studies deal with the traumatic origin, although degenerative changes in the cervical spine are also mentioned as one of the main causes of cervical disc herniations.

The aim of this study was to investigate the mechanical failure pattern of cervical herniated discs under complex cyclic loading in order to identify risk factors during head motion.

**Materials and Methods:** For this purpose, a new in vitro test method was developed to simulate typical everyday neck and head movements with extreme motions and loads, such as extensive smartphone use, overhead work, frequent head rotations or driving heavy vehicles. In a dynamic disc loading simulator, in vivo motion data [2] and axial loads [3] were applied to 6 cervical motion segments (C4-5, C6-7) of 4 human donor spines (19-48 years, Miyazaki degeneration degree 2-4 [4]). Long-term effects of these strains were attempted by exaggerating and combining the movement patterns. This dynamic test protocol was applied for a total of 3000 load cycles on the intact specimen, after injury (1mm) of the posterior longitudinal ligament (PLL) and after complete rupture of the ligament. Before and after each test step, a flexibility test was performed in a quasi-static spine loading simulator. Statistical analysis was performed using a Friedman test with Bonferroni post hoc correction ( $p\leq0.05$ ).

**Results:** In the intact state, no herniation could be provoked in any specimen by simulating everyday head movements. Only after injury of the PLL (1mm) and dynamic loading, nucleus extrusion could be detected in one specimen and a protrusion in another after excessive loading. Nucleus extrusion led to a slight increase in the range of motion of  $\pm 1^\circ$  in each direction of movement (Fig.1). Both specimens were obtained from young donors with only slight signs of degeneration.

**Discussion:** In this study, a new test method was developed with which 3000 complex load cycles can be applied to investigate long-term effects of everyday movements on the occurrence of cervical disc herniations. In general, even complex "long-term loading" does not appear to cause a herniation in the intact disc. The risk for a cervical herniated disc increased due to the injury of the PLL, which seems to have a protective influence on the disc. In addition, younger patients may have a higher risk of cervical disc herniation.

[1] Manchikanti et al., Pain Physician;12:E35-70(2009) [2] Anderst et al., J Biomech;48:1286-1293(2015) [3] Bell et al., J Biomech;87:107-113(2019) [4] Miyazaki et al., J Spinal Disord Tech;21:288-292(2008)

Fig. 1

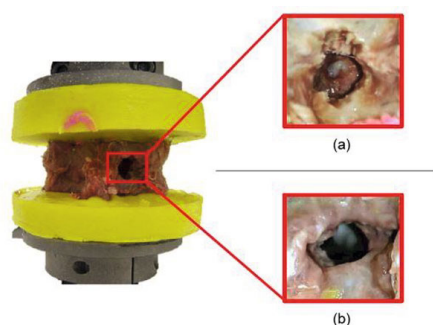


Fig. 1 Specimens with (a) clear nucleus extrusion after the physiological and (b) nucleus protrusion after the exaggerated test protocol, view from the posterolateral annulus

## V 52

### Anterior cervical disc arthroplasty for the treatment of degenerative disorders Clinical outcome and MRI based findings of series of 24 patients with a mean follow-up of 11 years

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**Objective:** The ideal surgical technique for the treatment of degenerative disorders of the cervical spine has not been determined yet. Cervical disc arthroplasty (CDA) has been evolved to reduce the development of adjacent segment degeneration which might become symptomatic (sASD) and lead to repeated procedure. Studies with long-term clinical outcome and MRI data following CDA are rare.

**Material:** Retrospectively, a files of all patients who underwent CDA for degenerative disorder between 2005 to 2010 were identified. Inclusion criteria for further evaluation were a complete set of pre- and postoperative neurological status and at outpatient visit with a minimum follow-up of 1 year, and a detailed documentation of repeat procedures. At final follow-up a personal examination and MRI scan of the cervical spine was performed. Clinical outcome was assessed via Odoms criteria, Neck disability index (NDI). The degenerative status of the cervical spine based on the MRI scan was assessed using a five step grading system (range 0–1).

**Results:** A total of 100 patients were identified and 67 (32 males and 35 females) among those fulfilled inclusion criteria. One- and two-level CDA was performed in 50 and 17 patients, respectively. In twelve patients (18%) repeat procedure was performed. In ten among those procedures were performed for sASD (15%), the index segment was also revised in five among those sASD procedure. In a total of six cases CDA removal was performed due to implant associated complication (8.9%). At outpatient visits with a mean follow-up of 37 months (range 12–154 month) 34 patients were free of neck pain (54%) and 41 patients were free of radicular symptoms (67%). Thirty-nine patients attended (19 male and 20 female) attended the examination at final follow-up (mean 11 years, range 9–15 years), 28 patients were free of arm pain (71%), 22 patients were free of neck pain (56%), the mean NDI score was 12%, 30 patients (76%) reported clinical success according to Odoms. The mean grade of degeneration at the cranial and caudal adjacent segments was 0.595 and 0.385, respectively.

**Conclusion:** The clinical success rate following CDA for the treatment of degenerative disorders was 76% within 11 years. The sASD rate was 15% and rate for repeat procedure was 18%. Segmental degeneration of cranial adjacent segment was more severe compared to segments caudal to the CDA.

## V 53

### Blood spinal cord barrier disruption in patients with degenerative cervical myelopathy: Potential to restore?

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**Objective:** Blood spinal cord barrier (BSCB) disruption plays an elementary role in acute and neurodegenerative diseases of the spinal cord (SC). Especially the secondary pathomechanisms arising from the impairment of the BSCB cause further damage to the SC. This study was set out to detect BSCB disruption in patients with degenerative cervical myelopathy (DCM) preoperatively and possible recovery after surgical decompression of the cervical SC.

**Methods:** The study was prospectively enrolled with 58 DCM patients (25 female; 33 male; mean age  $62.0 \pm 12.0$  years) of which 38 were included. As neurological healthy controls, 49 (17 female; 32 male; mean age  $62.3 \pm 14.4$  years) patients with thoracic abdominal aortic aneurysm (TAAA) were recruited of which 38 were included. Preoperatively, CSF and bloodserum samples were taken. All participants underwent neurological examination including mJOA and NDI. In eight DCM patients, samples could be collected three months postoperatively. To assess the status of the BSCB we used the Reiber diagnostic, measuring Albumin, IgG, IgA and IgM (all mg/dl). Quotients (CSF/serum) were calculated ( $n \times 10^{-3}$ ) for all parameters (QIgG, QIgA, QIgM and QAlb). The individual age-related reference range of QAlb for patients and controls were calculated:  $QAlb = (4 + \text{age}/15) \times 10^{-3}$ .

**Results:** Clinical status differed significantly between patients and controls (mJOA: DCM  $10.4 \pm 3.2$ , TAAA  $17.4 \pm 1.2$ ,  $p < .001$ ; NDI: DCM  $42.3 \pm 19.4$ , TAAA  $4.6 \pm 7.7$ ,  $p < .001$ ). In the DCM group 32 patients showed a BSCB disruption. In the control group none of the patients had a BSCB disruption. QAlb as expression of BSCB impairment significantly differed between groups (QAlb: DCM:  $12.6 \pm 8.2$ ; TAAA:  $5.1 \pm 1.8$ ,  $p < .001$ ). Intrathecal immunoglobulin concentrations significantly differed between groups (QIgG DCM  $5.8 \pm 3.9$ , TAAA  $2.5 \pm 0.9$ ,  $p < .001$ ; QIgA DCM  $3.4 \pm 2.4$ , TAAA  $1.5 \pm 0.8$ ,  $p < .001$ ). Three months after decompressive surgery eight DCM patients agreed to be lumbar punctured again. Postoperatively, results reveal a reduction of QAlb for all patients (QAlb DCMpre  $12.6 \pm 1.3$ , DCMpost  $7.0 \pm 1.0$ ,  $p < .001$ ). In three patients BSCB disruption was completely restored.

**Conclusion:** DCM patients present with BSCB disruptions. Higher concentrations of intrathecal immunoglobulin as an expression of pathological diffusion were detected. Postoperatively, BSCB seems to restore after decompressive surgery. These results indicate BSCB disruption to be a relevant pathomechanism in DCM.

## V 54

### Endoscopic transnasal odontoidectomy for ventral decompression of the craniovertebral junction: surgical technique and clinical outcome in 19 cases

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**Objective:** Pathologies of the craniovertebral junction may result in compression of the brainstem and symptoms of myelopathy. Anterior transnasal endoscopic decompression is recently considered a less invasive alternative to the transoral approach and transcervical approach. We hereby present a considerably large case series with focus on the operative technique and neurological clinical outcome.

**Methods:** We conducted a retrospective review of all consecutive patients treated for odontoidectomy in our neurosurgical department from January 2009 to December 2019. Demographics, pre- and postoperative clinical status, as well as operative technique, complications and follow-up were extracted and analyzed.

**Results:** In total, 22 transnasal operations were performed in 19 patients from January 2009 to 2020. All patients underwent

anterior transnasal CT-navigated full-endoscopic decompressive odontoidectomy. Median duration of symptoms before surgery was 3 months. Median preoperative mJOA Score was 16 points. Complications occurred in one patient who died from septic organ failure due to his initial diagnosis of osteomyelitis. More than 50% experienced a neurological improvement after surgery. Transient swallowing disturbances were observed in 41%, which mostly resolved at follow-up. Postoperative CT imaging showed sufficient decompression in 16 patients, 3 patients underwent a transnasal endoscopic re-decompression (16%). None had to undergo a different decompressive anterior approach.

## V 55

### Surgical treatment of spinal metastases of the cervicothoracic junction

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**Introduction:** Spinal metastases of the cervicothoracic junction (CTJ; C7-Th2) pose a challenge for treatment. The aim of our study is to compare surgical strategies for their treatment with respect to surgical complexity and associated complications.

**Methods:** 238 patients were surgically treated with spinal metastases of the CTJ in 2005–19 at 7 university centers in Europe. SINS, clinical, surgical and outcome data were assessed. Patients were divided into 4 groups: those with high comorbidities were only decompressed (1), decompression and instrumentation from posterior (2) or anterior (3) was performed in case of instability (SINS) dependent on location of myelon compression (2/3). 360° anterior-posterior instrumentation was performed in extensive lytic lesions and in cases with low comorbidities (4).

**Results:** 37 patients were treated in (1) (15%), 127 patients in (2) (53%), 18 patients in (3) (8%) and 56 patients in (4) (24%). Medium SINS was (1) 7, (2+3) 11 and (4) 12. In (1–2) patients presented with worse neurological function than (3–4), whereas in (1) systemic tumor burden was highest. In (2–4) 83–89% suffered from mechanical pain, in (1) 50%. Complications occurred in (1) 17%, (2) 43%, (3) 22% and (4) 32%. Hardware failure (HwF) during follow-up occurred exclusively in (2) and led to surgical revision in 6 cases. HwF occurred exclusively in monocortically placed massa lateralis screws (mMLS) in the cervical spine. In case of bicortical massa lateralis screws (bMLS) or pedicle screws (PS) no HwF was observed at 10 months follow-up.

**Discussion:** The biomechanical loading capacity of dorsal instrumentation alone seems to have a decisive influence on revision rate in metastases of C7-Th2. In patients with favorable comorbidity rate, the extension of life expectancy through new therapy options should play a crucial role in choosing the right surgical strategy. Attention should be paid to the distinct biomechanical properties of the CTJ, with 360° stabilization and placement of bMLS or PS preferable to mMLS in our multicentric cohort.

## V 56

### Surgical treatment and neurological outcome of infiltrating intramedullary astrocytoma WHO II–IV

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**Objective:** Primary malignant spinal astrocytoma are rare oncological entities with rapid neurological deterioration and limited median survival. Evidence on surgical therapy, adjuvant treatment and neurological outcome is sparse. Our aim is to describe the treatment algorithm and clinical outcome of patients with infiltrating spinal astrocytoma graded WHO II to IV.

**Methods:** We conducted a multicentered retrospective study of all consecutive patients treated for spinal intramedullary astrocytoma WHO II–IV in 5 high volume neurosurgical departments from 2008 to 2019. Pilocytic astrocytomas were excluded. Data on surgical technique, perioperative neurological status, adjuvant oncological therapy and clinical outcome was assessed.

**Results:** In total, 40 patients were included (diffuse astrocytoma n=11, anaplastic astrocytoma WHO III n=12, WHO IV n=17). Only 41% were functionally independent before surgery (modified McCormick Grade I or II), most patients presented with moderate disability (grade III in 46.2%). Most patients underwent a biopsy (n = 18, 45%) or subtotal tumor resection (n = 15, 37.5%). 49% of the patients deteriorated after surgery. Patients with WHO III and IV tumors were treated with combined radiochemotherapy. Median overall survival was 5 years in WHO II, 25.7 months in WHO III, and 7.4 months in WHO IV astrocytomas. Preoperative clinical status and WHO° significantly influenced the overall survival while the extent of resection did not.

**Conclusion:** Infiltrating intramedullary astrocytoma WHO II–IV present rare entities with dismal prognosis. Due to the high incidence of surgery related neurological impairment, the aim of the surgical approach should be limited to biopsies to obtain tissue for histopathological diagnostics or at most tumor debulking in cases with rapidly progressive severe preoperative deficits.

## V 57

### Tumor recurrence and functional outcome following spinal meningioma surgery: Institutional experience with 123 cases

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**Object:** Spinal meningiomas (SMs) account for 12% of all meningiomas. Clinicoradiological and immunohistochemical factors were analyzed with regard to the prediction of functional outcome, surgical adverse events, and tumor recurrence.

**Methods:** Medical records of 123 patients who underwent surgery for SM between 2000 and 2019 were retrospectively reviewed with regard to demographic parameters, imaging features, neurological function, and immunohistochemical items. Medical history, radiological sign of dural attachment, dural tail sign, T2 hyperintensity of the spinal cord, tumor size, spinal level, Simpson grade of surgery and histopathology were analyzed to predict tumor recurrence and functional outcome. Neurological function was graded according to the Modified McCormick Scale (MMS) and dichotomized as "good (grade I+II)" and "poor (grade III–V)" function.

**Results:** One hundred and fourteen (92.7%) WHO grade I and 9 (7.3%) WHO grade II SMs were included in this study. Univariate analysis identified a baseline T2 hyperintensity of the spinal cord, baseline symptom duration  $\geq 4$  weeks, age  $\geq 66$  years, and dural tail sign as predictors of poor MMS. Baseline T2 hyperintensity of the spinal cord (OR=13.3, 95% CI=3.4–52.1, p<0.001) and age  $\geq 66$

years (OR=10.3, 95% CI=2.6–41.1,  $p=0.001$ ) were independent predictors of a poor MMS grade at discharge after SM surgery in the binary logistic regression analysis. Median (range) follow-up (including MRI surveillance) was 12.0 (3.0–120.0) months in 80 cases. Recurrence of tumor was observed in two cases (2.5%). Kaplan-Meier analysis (log-rank test) revealed that WHO grade II, cervical location, ventral tumor attachment, male sex, diabetes, Simpson grade (III&IV), and MIB-I index  $\geq 5\%$  were associated with an increased risk of tumor recurrence. Cox regression analysis revealed the MIB-I labeling index  $\geq 5\%$  as an independent risk factor for tumor recurrence (HR: 1.77, 95% CI: 1.01–3.11,  $p=0.047$ ).

**Conclusion:** Baseline T2 hyperintensity, especially in the elderly patients, is a strong predictor of prolonged recovery after spinal meningioma surgery. A policy of maximal safe resection of SMs prolongs the recurrence-free survival in those with SMs having high proliferative activity.

## V 58

### Cement-augmented Carbon-Fiber-reinforced pedicle screw instrumentation for spinal metastases: safety and efficacy

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**Study Design:** Monocentric cohort study of a consecutive cohort of patients with thoracolumbar spinal metastases undergoing posterior instrumentation with fenestrated Carbon-fiber reinforced Poly-Ether-Ether-Ketone (CFRP) pedicle screws.

**Objective:** To investigate the complication rates and long-term implant failure rates after instrumentation with a CFRP system.

**Summary of Background Data:** CFRP pedicle screw systems improve adjuvant treatment planning and visualization on follow-up imaging. The adaptability of these novel systems for cases requiring cement-augmentation with Polymethylmetacrylate (PMMA) and minimally-invasive surgery approaches (MIS) has not yet been investigated.

**Methods:** We retrospectively reviewed demographics, perioperative Karnofsky Performance Scale (KPS) scores, complication rates and implant failure rates.

**Results:** Between June 2016 and November 2019, 51 consecutive patients underwent cement-augmented CFRP pedicle screw instrumentation at our institution. Mean age was 68 years (SD 10.5), 54.9% were female, median pre- and postoperative KPS were 80, respectively. Most common primary entities were breast (25.5%), non-small cell lung (15.7%) and prostate (13.7%) cancers. Of 428 placed screws, 293 (68.5%) were augmented with PMMA, a mean 6 per patient (SD  $\pm 2$ ). Screws were inserted via an MIS technique in 54.9% of cases. In total, 11.8% of patients had immediate postoperative sequelae related to the cement. Pulmonary cement embolisms were noted in 3 patients, another 2 had paravertebral extravasation and 1 had an embolism into a segmental artery. Of these 6, only 2 patients with pulmonary embolisms reported related symptoms. Follow-up was available for 80.4%. After a mean 9.8 months, screw loosening was noted in 11.8% of cases on computed tomography, although asymptomatic in all but one patient. Screw pull-out did not occur. Neither cement-related ( $p=0.353$ ) nor general complication rates ( $p=0.507$ ) differed significantly between open and MIS techniques.

**Conclusion:** Percutaneous cement-augmented CFRP pedicle screw instrumentation facilitates artifact-reduced postoperative imaging, while maintaining a risk profile and implant failure rates comparable to conventional metallic instrumentation.

## V 59

### Health Related Quality of Life in Patients undergoing Pedicle Subtraction Osteotomy for Sagittal Imbalance: a single center experience of 65 patients

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**Background:** Pedicle subtraction osteotomy (PSO) was first described in 1985 to correct kyphotic spinal deformities. In the last decade, the method becomes more popular due to the increasing rate of iatrogenic flat back syndromes and better understanding of the concept of sagittal balance. To date, there is a lack of studies reporting on patient satisfaction after PSO. Therefore, the purpose of this study was to evaluate the impact of PSO for sagittal imbalance on patient self-reported satisfaction two years postoperatively.

**Methods:** 65 patients that were treated with a thoracolumbar PSO between 2011 and 2018 were asked to perform self-reporting forms two years postoperatively. Outcome was measured using the visual analog scale (VAS) for back and leg pain, the Oswestry Disability Index (ODI) and the EQ-5D. Additionally the Patient Satisfaction Index (PSI) rating four grades (A: very satisfied to D: not satisfied) and walking range were evaluated.

**Results:** 61.9% of patients ( $n = 40/65$ ) reported a PSI grade "A" 24 months postoperatively. The operation showed significant improvements in back pain, measured by the VAS (preoperative:  $8.1 \pm 1.2$  vs. 24m postoperative:  $2.9 \pm 1.9$ ;  $p < 0.001$ ), as well as ODI scores (preoperative:  $57.7 \pm 13.9$  vs. 24m postoperative:  $32.6 \pm 18.9$ ;  $p < 0.001$ ) and walking range (preoperative:  $589 \pm 1,676$ m vs. 24m postoperative:  $3,265 \pm 3,405$ m;  $p < 0.001$ ). EQ-5D scores after 24 months reached a mean of 0.7233 ( $\pm 0.26$ ).

**Discussion:** Despite the complex surgical procedure and a relatively high overall complication rate, patient satisfaction 24 months after PSO for sagittal imbalance is high. Quality of life seems to be significantly lowered in patients suffering from sagittal imbalance and might be improved by operative procedures restoring sagittal balance. Nevertheless, further prospective investigations assessing patient satisfaction are required.

## V 60

### Comparison of 2-rod and 4-rod instrumentation for degenerative scoliosis correction

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**Study design:** Retrospective observational study.

**Objective:** The aim of this study was to compare clinical outcomes, sagittal alignment and mechanical complications in patients with degenerative scoliosis operated by 2-rod versus 4-rod instrumentation.

**Summary of background data:** Degenerative scoliosis instrumentation to the pelvis is associated with complications such as proximal junctional kyphosis (PJK) or non-union. The use of 4-rod instrumentation is intended to decrease the incidence of mechanical failure.

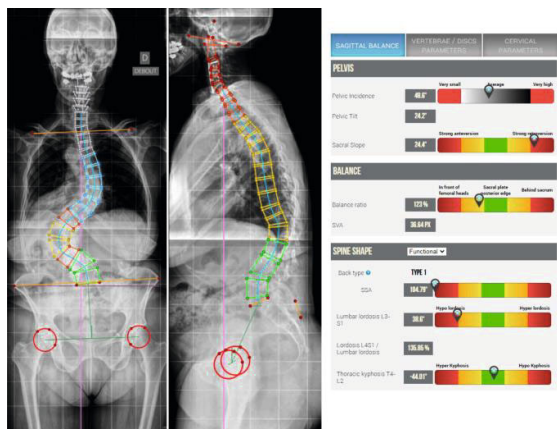
**Methods:** The study included 97 patients with average 3.9-year follow-up after degenerative scoliosis correction and compared 2-rod (2R) instrumentation ( $n=58$ ) to 4-rod (4R) instrumentation with interbody cages ( $n=39$ ). Clinical scores were assessed: VAS, ODI, SRS-22, EQ-5D-3L. Radiographs were modeled using KEOPS software and measured coronal and sagittal alignment parameters, lumbar apex, number of vertebrae in lordosis and Roussouly type. The incidence of non-union and PJK were investigated.

**Results:** Clinical scores improved similarly in both groups ( $p < 0.05$ ). In the 2R-group, lumbar lordosis increased from  $42.6^\circ$  to  $52.8^\circ$  postoperatively ( $p < 0.0001$ ). During the first year, lordosis decreased to  $47.3^\circ$  ( $p=0.0086$ ), SVA ( $p=0.0003$ ) and pelvic tilt ( $p=0.0003$ ) increased. In the 4R-group, lumbar lordosis increased from  $46.6^\circ$  to  $52.5^\circ$  postoperatively ( $p=0.0140$ ) and remained stable. Non-union occurred in 56.9% in the 2R-group versus 0% in the 4R-group ( $p < 0.0001$ ). The number of vertebrae in lumbar lordosis increased from 4.8 to 6.0 (2R,  $p < 0.0001$ ) and 5.5 to 7.2 (4R,  $p < 0.0001$ ). PJK occurred in 13.8% (2R) versus 15.4% (4R). In PJK, the length of lordosis increased, the lumbar apex shifted cranially and did not match with the Roussouly type: 36.2% (2R) versus 23.1% (4R).

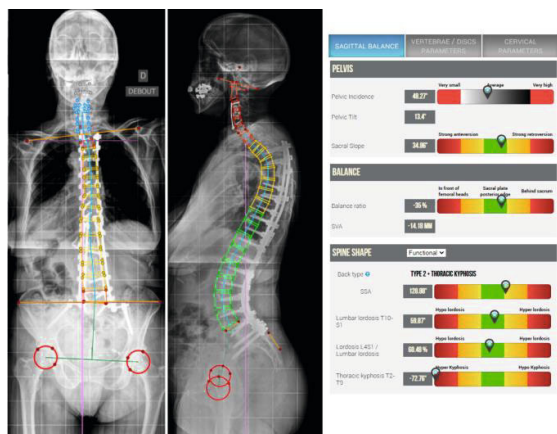
**Conclusion:** Four-rod instrumentation with interbody cages carried a lower risk of non-union and subsequent revision surgery than 2-

rod instrumentation. The PJK incidence was comparable in both groups and related to mismatches between lumbar apex level and spinopelvic alignment type. Final clinical outcomes were similar with both techniques.

**Fig. 1**



**Fig. 2**



## V 61

### Spinal Cord Stimulation – a reasonable alternative treatment in patients with symptomatic adult scoliosis if surgical therapy is not suitable?

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**Introduction:** In adult scoliosis the asymmetric loading of weight-bearing structures promotes progressive degeneration leading to lower back pain (LBP) which can be accompanied by additional regional pain. For patients who do not respond to conservative therapy surgical treatment is considered a well-established method of addressing chronic back pain. Dorsal instrumentation and fusion can provide significant improvement of pain and ODI, however complication rates of up to 39% have been reported. As such, recent attempts have been made at expanding the surgical spectrum to include less invasive techniques in patients such as neuromodulation, specifically spinal cord stimulation (SCS). We therefore we aimed to evaluate its use in a larger cohort of adult scoliosis patients.

**Methods:** We prospectively analyzed 14 adult scoliosis patients receiving SCS treatment in our institution between February 2019 and May 2020. Adult scoliosis was defined as a Cobb angle of >10° in the coronal plane in skeletally mature patients. Clinical follow-up was performed at 3, 6 and 12 months following

implantation of an epidural SCS System. Patients reported NRS values for the categories of LBP and specific regional pain both at rest and in motion. Further, SF-36, Short form of the Profile of Mood States, Pittsburgh Sleep Quality Index and ODI were collected. The study was approved by the institutional Ethics Committee (EA2/093/13).

**Results:** In our cohort the average patient age was 71 years old (range 33–85) with an average BMI of 29 kg/m<sup>2</sup> (range 22–37 kg/m<sup>2</sup>). Scoliotic deformity of the thoracolumbar junction was the most common localization (10/14). Initial preoperative NRS of lower back pain (LBP) at rest was significantly reduced following SCS at three (43% reduction vs. preoperative, p=0.005) and six (49% reduction vs. preoperative, p=0.027) months follow-up. LBP in motion was also reduced at three (32% reduction vs. preoperative, p=0.005) and six (36% reduction vs. preoperative, p=0.010) months. Regional pain at rest was reduced at three (42% reduction vs. preoperative, p=0.002) and six (52% reduction vs. preoperative, p=0.014) and in movement at three (29% reduction vs. preoperative, 0.004) and six (34% reduction vs. preoperative, p=0.012). A reduction of NRS was reported for all categories at 12 months following SCS implantation, however these did not reach statistical significance.

**Discussion:** Our patient cohort was comprised of older adults (average age of 71) with above-average BMI (29 kg/m<sup>2</sup>), for whom the risks of corrective surgery must be carefully considered. Our results show that in these patients, neuromodulation can significantly reduce LBP as well as regional pain in the first six months following implantation. These findings indicate that SCS may provide a reasonable alternative in patients not willing or eligible to undergo extensive corrective surgery, or in those for whom corrective surgery has not adequately addressed LBP or regional pain

## V 62

### Safe sacropelvic screw positioning in patients with transitional lumbosacral vertebra

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**Introduction:** Spinopelvic anchoring of long spinal fusions are a common procedure in the surgical correction of spinal deformities. With a reported prevalence of 4–36% in the general population, lumbosacral transitional vertebrae (LSTV) are among the most common congenital spinal anomalies. The aim of the study was to assess the screw position and the incidence of complications due to misplacement of S1 Pedicle Screws (S1PS), S2 Alar Screws (S2AS), S2 Alar Iliac Screws (S2AIS) and Iliac Screws (IS) in patients with LSTV.

**Material/Methods:** Of the 819 patients included, 52 had LSTV. Three patients had to be excluded due to software incompatibility. For screw placement we used the software mediCAD (mediCAD Hectec GmbH, Germany). Screw complications were the affection of the spinal canal by S1PS, an affection of the sacroiliac joint (SIG) in S2AS and a vascular injury for all screw types.

[Table 1]

**Results:** We evaluated the placement of 5096 screws. None of the S1PS positioning resulted in spinal canal or vascular injury. The injury of the SIG by S2AS showed a dependence on the degree of expression of an LSTV (p<0.001). The frequency of vascular injury by S2AS showed no correlation with the degree of expression of an LSTV (p>0.05). The frequency of vascular injuries caused by S2AIS showed a significant correlation with the degree of expression of an LSTV (p<0.001). The angle of screw insertion had a significant influence on the frequency of vascular injuries for S2AS (p=0.001) and S2AIS (p=0.014).

**Discussion:** Our study shows that sacral anchoring of long spinal fusion using S1PS, S2AS and S2AIS is also possible for LSTV. The insertion of S1PS with the used angles is feasible in LSTV without increased risk for vascular injuries and spinal canal affection. The insertion of S2AS with a lateral angulation of 40° and a caudal angulation of 10° resulted in a lower incidence of vascular injuries and fewer SIG injuries in patients with LSTV.

S2AIS with 40° lateral angulation led to a reduction of vascular injuries compared to 60°. Similarly, the introduction of S2AIS with 0° sagittal angulation reduced the risk of serious complications compared to 10°. In IS, screw insertion with 20° lateral angulation led to significantly less breaches and significantly less vascular injuries compared to insertion with 35°. A caudal angulation of 45° resulted in significantly less breaches compared to 35° angulation, although it increased the risk of screw misalignment in the ischial fossa.

**Fig. 1**

Tabelle 1: Schraubendurchmesser, -länge und -einbringungswinkel

	Ø 1	Ø 2	Länge 1	Länge 2	Sagittale Ang. 1	Sagittale Ang. 2	Axiale Ang. 1	Axiale Ang. 2
S1PS	6.5 mm	-	45 mm	-	10°	25°	20°	30°
S2AS	6.5 mm	8.5 mm	45 mm	50 mm	10°	25°	30°	45°
S2AIS	6.5 mm	9.5 mm	65 mm	95 mm	0°	10°	40°	60°
IS	6.5 mm	9.5 mm	65 mm	95 mm	30°	45°	20°	35°

Table 1: Used screw diameters, length, and screw trajectory

	Ø 1	Ø 2	length 1	length 2	Sagittal Ang. 1	Sagittal Ang. 2	Axial Ang. 1	Axial Ang. 2
S1PS	6.5 mm	-	45 mm	-	10°	25°	20°	30°
S2AS	6.5 mm	8.5 mm	45 mm	50 mm	10°	25°	30°	45°
S2AIS	6.5 mm	9.5 mm	65 mm	95 mm	0°	10°	40°	60°
IS	6.5 mm	9.5 mm	65 mm	95 mm	30°	45°	20°	35°

## V 63

### Clinical and radiographic comparison of navigated spinopelvic fixation techniques: S2-alar-iliac screw versus iliac screw

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**Introduction :** Spinopelvic fixation is gaining in importance due to the proven good clinical results. It currently plays an important role in the treatment of spinal adult deformities, degenerative spinal diseases, tumors, traumatic fractures and infections. However, due to the complex anatomy and high biomechanical requirements it remains a challenge in spinal surgery. The most commonly used techniques are S2-alar iliac screw fixation (S2-AI) and the iliac screw fixation (IS). Currently the use of intraoperative navigation techniques allow intraoperative placement control and screw adjustment. Studies on results of navigated spinopelvic fixation are limited. The present study investigates the safety of spinopelvic fixation using intraoperative navigation. Additionally, the results of S2-AI are compared to IS.

**Methods:** The data of 61 patients undergoing navigated spinopelvic fixation at one single center between 01/2016 and 09/2019 were collected retrospectively. A positive vote of the ethics committee has been given (EA2/093/13). 52 (85.2%) patients underwent S2-AI and 9 (14.8%) patients underwent IS. Intraoperative navigation was carried out in 34 patients using the AIRO CT scanner, in 21 patients with the fluoroscopic O-arm imaging system and in 6 patients with the robotic Artis zeego system. Risk factors of complications were identified using univariate regression.

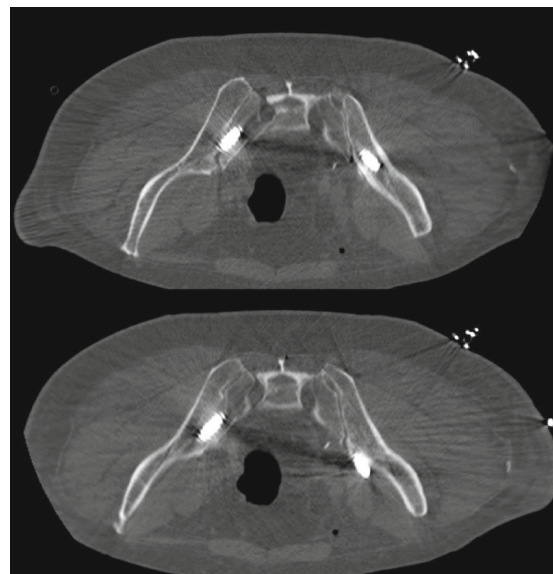
**Results:** In all patients a successful screw placement was achieved postoperatively without anterior, lateral or medial perforation. In 9 patients (14.8%) correction was necessary based on the intraoperative placement control (Fig. 1). One patient suffered an intraoperative vascular injury. The overall reoperation rate was 39.3% (36.5% for S2AI vs. 55.6% for IS). The most common causes were surgical site infection (SSI) (14.8%) and screw loosening (13.1%). The mean distance from the entry point to the skin was 55.88 mm in S2AI and 41.56 mm in IS. The number of SSI was significantly ( $p=0.027$ ) lower in the group S2AI than in

the group IS (9.6% vs. 44.4%). S2-AI was identified as the only protective factor regarding SSI (odds ratio = 0.13,  $p = 0.014$ ).

**Discussion:** The present study confirms that spinopelvic fixation can be performed safely using intraoperative navigation techniques. Screw misalignment can be identified and corrected intraoperatively. The S2AI are significantly superior to the IS in terms of SSI. The high rates of reoperations require further long-term studies.

**Fig.1:** Intraoperative misalignment of S2AI with following adjustment.

**Fig. 1**



## V 64

### Atlantoaxial Realignment in Odontoid fractures using the Goel – Harms Method: Even small Changes have a significant Impact on sagittal subaxial alignment

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**Introduction:** Atlantoaxial Fusion according to Goel –Harms has been accepted as a valuable procedure for surgical treatment of atlantoaxial fracture – dislocations. It has been hypothesized, that physiological lordotic realignment may be performed using this method. This is important especially with respect to the amount of lordosis, usually seen within C1 – 2. However, this hypothesis has never been proven. Moreover, there is paucity of information how changes of segmental lordosis may influence the sagittal balance of the subaxial c- spine.

**Aim of the study** was, to analyse,

1. if atlantoaxial lordosis following Goel – Harms surgery restores physiological lordosis
2. the impact of the treated segment c 1- 2 on subaxial sagittal alignment.

**Material & Methods:** We analysed sagittal x- rays of 63 patients with axis fractures within our clinical data bank. We looked at lordosis C 1- 2, C 1- 7, C 2- 7, C7 slope, distance of C 2 plumb line to C 7 plumb line (C2 – C7 plumb line). We analysed how the change of lordosis within C 1-2 (delta C1 – 2) influenced sagittal subaxial alignment. Statistics using SPSS, significance assumed for  $p$  value < 0,05.

**Results:** mean age 62 years, 57,1% female, 42,9 % male.

- We found lordotic angulation within C1 – 2 in all individuals, ( $27,7^\circ \pm 11,1^\circ$  before and  $26,1^\circ \pm 9,5$  after surgery,  $p = 0,143$ ).
- Delta C1-2 was significantly correlated with postop C7 Slope ( $r = -0,37$ ,  $p = 0,003$ ), postop C2- C7 plumb line ( $r = -0,4$ ,  $p = 0,01$ ), however not with postop lordosis C2-C7 ( $r = -0,2$ ,  $p = 0,08$ ) or postop lordosis C1-C7 ( $r = -0,126$ ,  $p = 0,32$ ).

#### Conclusion:

1. Physiological lordosis within the atlantoaxial joint may be restored using fixation /fusion according to Goel–Harms. There is no significant difference when postop alignment in this segment is compared to preop alignment.
2. the change of lordosis within this segment under surgery may be considered to be small and is not significant here, however it *does* have an impact on subaxial sagittal balance with respect to C 7 slope and distance of C 2 to C7 plumb line. These results emphasize the importance of the atlantoaxial joint for the cervical subaxial balance.

#### V 65

##### Alignment shift between preoperative CT and intraoperative CT for navigated spinal instrumentation

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**Introduction:** State-of-the-art intraoperative imaging for spinal navigation is associated with high acquisition and maintenance costs. Alternatively, spinal navigation can be performed by surface-matching registration of a preoperative CT but the position change from supine to prone may result in an alignment shift that could lead to navigation inaccuracy. To test this hypothesis, we determined the spinal alignment shift based on pre- and intraoperative CT data sets in patients undergoing navigated posterior instrumentation.

**Materials/Methods:** All patients that underwent navigated, subaxial, posterior instrumentation with intraoperative CT imaging between 2014 and 2017 and in whom an additional, preoperative CT was available were included. The alignment shift between the preoperative (supine) and intraoperative (prone) CT before screw insertion was determined using sagittal and transverse alignment parameters that we defined as "modified Cobb angle" (CA), "sagittal plumb line" (PL) and "index level translation" (T). Alignment parameters were additionally analyzed according to the anatomic region, the indication for surgery, the presence of an instability risk factor, previous instrumentation and the instrumentation length. Data was collected and analyzed by an independent physician not involved in the patients' care.

**Results:** We identified 104 patients with a median age of 66 (IQR 56–75) and comparable female-to-male ratio. The indication for surgery was degenerative disease (35/104; 34%), tumor (35/104; 34%), trauma (21/104; 20%) and infection (13/104; 12%). The median instrumentation length was 5 segments (IQR 4–6). Pre- and intraoperative alignment parameters differed in 98% for CA, 92% for PL and in 29% for T with significant differences in the median CA [preop:  $14,8^\circ$  (IQR 7–24) vs. intraop:  $16,1^\circ$  (IQR 7–28); \* $p < 0,05$ ] and mean T [preop:  $4,6 \pm 6,4$  mm vs. intraop:  $4,8 \pm 6,4$  mm; \* $p < 0,05$ ]. Region-based analysis showed that CA most reliably detected shifts in the cervical-thoracic spine and PL in the thoraco-lumbar spine (\* $p < 0,05$ ). Overall, significant alignment shifts were more likely if a previous instrumentation existed at the operated level (\* $p < 0,05$ ) and if instrumentation longer than 5 segments was required (\* $p < 0,05$ ). The indication for surgery or presence of an instability risk factor had no significant effect.

**Discussion:** Spinal alignment shifts due to patient positioning occur frequently and across all regions of the subaxial and particularly in the cervical spine, which needs to be considered as a source of inaccuracy when performing navigation based on preoperative (supine) CT alone. The presence of a previous instrumentation and the need for long-segment instrumentation appear to be additional risk factors for greater alignment shifts.

#### V 66

##### Dynamic strains on spinal cord tissue in cervical spinal canal stenosis: first data on a potential additive mechanic stress in spinal cord deterioration

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**Background:** Within pre-studies, an increased spinal cord movement at level of cervical spinal canal stenosis has been demonstrated among affected patients<sup>1</sup>. It still remains unclear, how the dynamic effects evolve across the entire cervical spinal cord.

**Methods:** Interim analysis of a prospective longitudinal trial on patients suffering from spinal canal stenosis. 15 patients with cervical stenosis at level C5/C6 (age  $55,2 \pm 15,0$  yrs) and 15 controls (age  $45,5 \pm 10,1$  yrs,  $p = 0,107$ ) were compared. Each participant received an optimized prospective ECG-triggered phase-contrast-MRI in sagittal orientation (3T-MRI, spatial resolution  $1 \times 1 \times 3$  mm<sup>3</sup>,  $venc$  5 cm/s, PEAK-GRAPPA). Spinal cord movement is assessed by a standardized ROI (16 mm<sup>2</sup>) per Segment C2 to C7 using NORA2. Parameter of interest is the velocity-index (VI), that is calculated as maximum velocity per segment in C3 – C7 in relation to the maximum velocity at segment C2, respectively. This partially corrects for interindividual biodynamic differences (e.g. body size, heart rate, breathing) and gives information on the compressive or lengthening effect of the spinal cord tissue in respect to the reference level C2. Means were compared by t-test; for statistical significance  $p < 0,05$  was required.

**Results:** Patients showed a significantly increased VI from level C4 to C7 (Tab. 1). An increase of the VI towards level of stenosis and a caudal decrease was observed (Fig. 1). 73% of the patients showed a VI  $> 2$  at level C5 and 53.3% a VI  $> 2,5$ . In contrast only 20% of all healthy controls reached a VI  $> 2$  at level C5 and none a VI  $> 2,5$ .

**Discussion:** This is the first study to demonstrate a dynamic alteration of spinal cord movement across the entire cervical spine. The VI among patients provide objective on an upbuilding stretch followed by a caudal compressive strain of the spinal cord tissue due to cervical spinal canal stenosis. This underlines the mechanic stress as possible contributing mechanism on spinal cord deterioration.

1 Wolf K et al. Spinal Cord 2018

2 www.nora-imaging.org

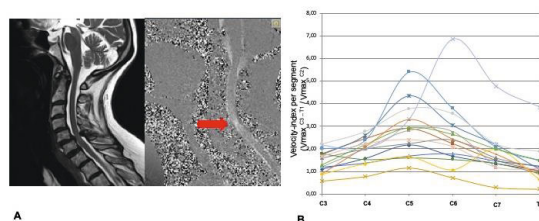
**Table 1:** Mean  $\pm$  standard deviation of the velocity index (VI) per segment C3 to C7. \* VI is significantly increased among patients from level C4 to C7 compared to healthy controls. \*\* The decrease of the mean VI from level C5 to level C7 is significant,  $p = 0,008$ .

**Figure 1:** A – Example of a patient. Conventional T2-weighted MRI on the right and corresponding phase image on the left. Velocities are encoded within a scale of grey. The red arrow indicates the evident change of brightness at level of stenosis. B – Progress of the VI per cervical segment C3 to T1 within 15 patients. Despite some variability, VI increases towards the level of stenosis with a following decrease.

Fig. 1

Velocity-Index per segment (Vmax <sup>C3-7</sup> / Vmax <sup>C2</sup> )	patients (n=15)	controls (n=15)	p-value
C3	1.47 ± 0.5	1.27 ± 0.5	0.276
C4	1.95 ± 0.5	1.48 ± 0.5	0.017*
C5	2.78 ± 1.1 **	1.38 ± 0.6	0.000*
C6	2.57 ± 1.5	1.34 ± 0.4	0.005*
C7	1.79 ± 1.0 **	1.13 ± 0.4	0.021*

Fig. 2



## V 67

### Cervical spine fusion to C7; is it necessary to extend the fusion to the first thoracic vertebra? – Retrospective analysis of 2590 patients

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**Introduction:** Cervical spine fusion is a standard surgical procedure. In many cases, the pathology ends at the level C6/7 and spares C7/Th1. Recently for those cases, an extension of the fusion to the first thoracic vertebra was recommended as a measure to avoid complications, especially the adjacent segment disease. To test that hypothesis, we retrospectively analyzed an extensive series of patients with cervical spine fusion ending caudally at C7.

**Material & Methods:** From 1994 to 2016, cervical spine fusion starting from the sub-axial cervical spine and ending at the level C6/7 was performed in 2590 patients in our department. The indication of fusion to C7 was degenerative disease in most cases (2490 patients), fractures in 32 patients, tumors in 25 patients, deformity in 25 patients, and spondylodiscitis in 18 patients. One level fusion was performed in 680 patients, two levels in 959 patients, three levels in 573 patients, and four levels in 378 patients. A retrospective analysis was performed regarding the necessity of reinterventions in the segment C7/Th1. Rate, causes, and time-lapse until the adjacent segment disease occurred were studied.

**Results:** In 1730 patients, an anterior fusion was performed, in 350 patients, a posterior only approach, and in 490 patients, a combined anterior and posterior approach was primarily performed. The mean follow-up of the 2590 patients was 56 months (range 12 months to 180 months). Symptomatic adjacent segment C7/Th1 necessitating surgical intervention was indicated in 27 patients (1.04%) after a mean of 36 months (range 6 to 52 months). There were 15 females and 12 males with a mean age of 56 years (range 39 to 75). All the adjacent segment disease patients were primarily operated for degenerative disease. Most cases (18 patients) were after three level-fusion, five patients were after 2-levels fusion, and two patients after one-level fusion. The number of fused levels and the surgical approach did not significantly affect the rate of the adjacent segment disease. (p=0.12, and 0.14)

**Conclusions:** Adjacent segment disease at the C7/Th1 after fusion to C7 is extremely rare (1.04%) after a mean follow-up of 56 months. In the absence of pathological changes in the C7/Th1 disc, It is not necessary to extend the fusion to the first thoracic vertebra.

## V 68

### AOSpine PROST (Patient Reported Outcome Spine Trauma) – validation of the Dutch and English versions

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**Objective:** In the absence of an outcome instrument that is specifically designed and validated for traumatic spinal column injury patients it is difficult to measure the effect size of various treatment options. The AOSpine Knowledge Forum Trauma initiated a project and developed the Patient Reported Outcome Spine Trauma (AOSpine PROST) consisting of 19 items. The psychometric properties of the Dutch (NL) and English (ENG) language versions of the tool were investigated in an international multicenter validation study.

**Material/Methods:** Patients were recruited from four level-1 trauma centers from the Netherlands and North America. The study consisted of 3 parts: cross-sectional, test-retest, and responsiveness. For concurrent validity, next to AOSpine PROST also SF-36 was filled out by patients. Patient characteristics were analyzed using descriptive statistics. Floor and ceiling effects as well as the number of inapplicable and missing questions were analyzed for content validity. Cronbach's  $\alpha$  and item-total correlation coefficients (itcc) were calculated for internal consistency. Spearman correlation tests were performed within AOSpine PROST items and in correlation to SF-36. Test-retest reliability was assessed using Intraclass Correlation Coefficients (ICC). Responsiveness of the Dutch version was assessed by calculating effect sizes (ES) and standardized response mean (SRM). Factor analysis was performed to explore any dimensions within AOSpine PROST.

**Results:** Out of 196 and 179 enrolled patients, 162 (82.7%) and 163 (91.1%) were included in the NL and ENG validation study, respectively. Content validity showed good results, and no floor and ceiling effects were seen. The internal consistency was excellent (ENG: Cronbach's  $\alpha=0.97$ ; itcc 0.50-0.90, NL: Cronbach's  $\alpha=0.96$ , itcc 0.50-0.86), with also good Spearman correlations (ENG: 0.29-0.85, NL 0.25-0.79). Also test-retest reliability was excellent (ENG: ICC=0.97, NL: ICC=0.92). The strongest correlations of AOSpine PROST with SF-36 were seen with the physical components (0.69-0.82; p<0.001). Factor analysis revealed 2 possible dimensions (Eigenvalues >1), explaining 75.7% (ENG) and 65.4% (NL) of variance. Concerning responsiveness analysis, very good results were seen with ES=1.81 and SRM=2.03 (p<0.001).

**Conclusion:** Very satisfactory results were obtained for reliability, validity and responsiveness of the Dutch and English versions of the AOSpine PROST, a disease-specific patient-reported outcome measure for traumatic spinal column injury patients. It is considered as a valuable tool, and has the potential to contribute to the reduction of ongoing controversies in spine trauma care.

## V 69

### Reliability analysis of the AOSpine CROST (Clinician Reported Outcome Spine Trauma): a tool to evaluate and predict outcomes from clinician's perspective

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**Objective:** Besides a patient reported outcome measure, there is also need for a simple, reliable and quick to administer tool that is completed by the treating surgeons. It would formalize the most relevant clinical and radiological assessment parameters, and enables them to evaluate and predict the clinical and functional outcomes of spine trauma patients: the AOSpine CROST (Clinician Reported Outcome Spine Trauma). This study reports on the development of the tool as well as the results of an initial reliability study.

**Material/Methods:** The AOSpine CROST was developed using an iterative approach of multiple cycles of development, review and revision including an expert clinician panel. Subsequently, a reliability study was performed among an expert panel who were provided with 20 spine trauma cases, administered twice with a four-week interval. The results of the developmental process were analyzed using descriptive statistics, the reliability per parameter using Kappa statistics, inter-rater agreement using Intraclass Correlation Coefficient (ICC), and internal consistency using Cronbach's  $\alpha$ .

**Results:** The AOSpine CROST was developed and consisted of 10 parameters, 2 of which are only applicable for surgically treated patients ("Wound healing" and "Implants"). A dichotomous scoring system ("yes" or "no" response) was incorporated to express expected problems for the short-term and long-term. In the reliability study, 16 (84.2%) participated in the first round and 14 (73.7%) in the second. Intra-rater reliability was fair to good for both time-points ( $\kappa = 0.40$ -0.80 and  $\kappa = 0.31$ -0.67). Results of inter-rater reliability were lower ( $\kappa = 0.18$ -0.60 and  $\kappa = 0.16$ -0.46). Inter-rater agreement for total scores showed moderate results (ICC = 0.52-0.60) and the internal consistency was acceptable ( $\alpha = 0.76$ -0.82).

**Conclusion:** The AOSpine CROST, an outcome tool for the surgeons, was developed using an iterative process. An initial reliability analysis showed fair to moderate results and acceptable internal consistency. Currently, further studies are being performed to test the tool in prospective studies. Once further validated, this tool has the potential to be used in daily clinical practice and for research purposes in order to create and contribute to evidence-based and patient-centered care.

## V 70

### Spring Distraction System to Correct Early Onset Scoliosis: 2 Year Follow-up Results from 24 Patients

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**Objective:** Current surgical treatment of Early Onset Scoliosis (EOS) is performed with either Traditional Growing Rods or Magnetically Controlled Growing Rods, which are distracted periodically and have a very high complication rate. We developed the Spring Distraction System (SDS), which uses a compressed spring to continuously correct the curve while stimulating spinal growth (Figure 1). It does not have to be periodically lengthened and can be used with any instrumentation system. Our aim was to establish efficacy and safety of SDS in terms of curve correction, spinal growth, and complications.

**Material/Methods:** All primary- and revision patients (conversion from failed other systems) who were implanted with SDS and with  $\geq 2$  years follow-up were included. Data on demographics, surgical parameters and complications were prospectively collected. Main coronal curve angle, L1-S1 lordosis, T5-T12 kyphosis, T1-T12, T1-S1 spinal length (measured as a spline curve through the midpoint of each vertebral endplate) and spring length increase were measured on calibrated radiographs. Length increases (from immediately postoperatively to latest follow-up) were expressed in mm/year. Results were compared between primary- and revision patients.

**Results:** We included 24 patients (18 primary and 6 revision cases) with a mean of  $2.3 \pm 0.3$  year follow-up. The cohort included 11 boys and 13 girls. There were 5 idiopathic, 7 congenital, 3 syndromic and 9 neuromuscular patients. Mean age at surgery was 8.4 and 11.2 years for primary- and revision patients respectively. Results can be seen in Table 1. In primary patients, main coronal curve was reduced from  $65^\circ$  to  $33^\circ$ , and was maintained at latest follow-up. For revision cases, main curve decreased from  $46^\circ$  to  $42^\circ$  but increased again during follow-up. During follow-up, kyphosis increased  $10^\circ$  in both primary- and revision patients. Mean spring length increase during follow-up was 10mm/year. Primary- and revision patients had similar increases in T1-S1 length (primary: 13mm/year, revision: 14mm/year) and T1-T12 length (primary: 10mm/year, revision: 9mm/year). Nine complications occurred requiring re-operation. In addition, 7/24

patients (29%) had their spring retensioned as their spinal growth exceeded expected growth velocity.

**Conclusion:** Spring distraction may be an effective treatment for EOS to control the curve and guide spinal growth without the need for repetitive distractions.

Fig. 1

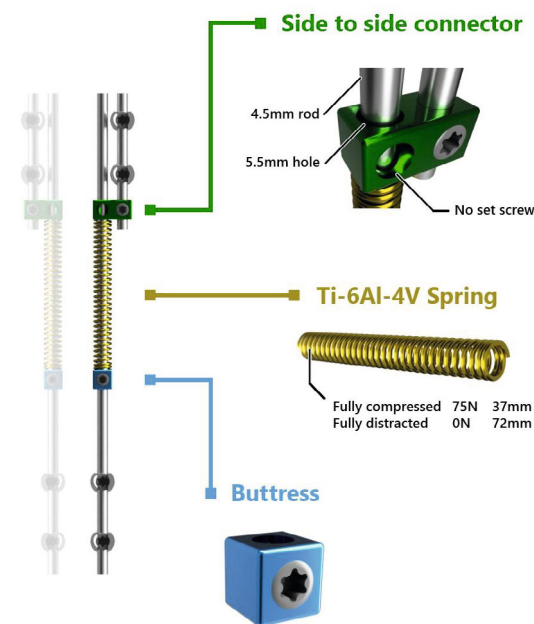


Fig. 2

Table 1: Radiographic results

	Primary cases (N=18)			Revision cases (N=6)		
	Pre-operative	Post-operative	Latest follow-up	Pre-operative	Post-operative	Latest follow-up
Main curve ( $^\circ$ )	65.0 $\pm$ 16.2	33.2 $\pm$ 11.8	35.6 $\pm$ 15.6	45.9 $\pm$ 21.9	41.6 $\pm$ 22.8	55.8 $\pm$ 22.8
Secondary curve ( $^\circ$ )	34.3 $\pm$ 15.2	21.6 $\pm$ 14.3	23.1 $\pm$ 13.5	24.4 $\pm$ 7.86	21.0 $\pm$ 9.66	23.9 $\pm$ 6.80
T1-T12 length (mm)	192 $\pm$ 26.7	199 $\pm$ 24.9	222 $\pm$ 28.4	209 $\pm$ 28.6	214 $\pm$ 30.6	235 $\pm$ 35.9
T1-S1 length (mm)	319 $\pm$ 41.4	330 $\pm$ 37.8	362 $\pm$ 44.4	344 $\pm$ 34.1	356 $\pm$ 34.6	390 $\pm$ 46.5
Instrumented length (mm)	-	259 $\pm$ 65.0	286 $\pm$ 75.1	-	220 $\pm$ 39.0	241 $\pm$ 41.0
Spring length (mm)	-	70.8 $\pm$ 22.2	96.0 $\pm$ 31.9	-	58.1 $\pm$ 20.4	78.3 $\pm$ 25.3
L1-S1 lordosis ( $^\circ$ )	47.8 $\pm$ 13.4	41.2 $\pm$ 10.4	49.6 $\pm$ 19.4	52.5 $\pm$ 15.2	51.2 $\pm$ 14.2	58.5 $\pm$ 13.8
T5-T12 kyphosis ( $^\circ$ )	18.6 $\pm$ 21.0	16.7 $\pm$ 13.2	27.0 $\pm$ 15.1	33.4 $\pm$ 26.2	36.3 $\pm$ 26.2	46.0 $\pm$ 27.7
<b>Complications requiring re-operations</b>						
Connector Failure		0			2	
Anchor failure		2			0	
Rod Fracture		1			0	
Implant protrusion		2			1	
Deep Surgical Site Infection		1			0	
Retensioning of spring		5			2	

## V 71

### A Novel Device to Enhance Bone-to-Screw Interface in Spine Surgery: 2-year results in an FIH Safety Study

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**Objective:** Optimal fixation between screw and bone is essential to achieve successful outcomes in spinal surgery. Currently, enhanced fixation is sought by augmenting a procedure with larger diameter

screws and / or bone cement such as polymethyl methacrylate or calcium-based cements.

A new unique braided Polyethylene Terephthalate (PET) sleeve was used to act as a plug in bone prior to the insertion of the pedicle screw, to enhance the quality of screw-to-bone interface particularly in worst case fixation scenarios such as revisions for screw loosening. With biomechanical studies having proven very favorable, the study aim was to investigate the safety profile for the use of such an implant in spinal surgery.

**Material/Methods:** Following Ethical Committee approval, patients aged 21 to 75 years, undergoing a short-segment lumbar posterior instrumentation for degenerative lumbar spine pathology were approached for participation in a trial conducted at one institution. After completing a structured consenting process, data on age, gender, body mass index (BMI) and co-morbidities was collected. Additional data on visual analogue score (out of 100) (VAS), Oswestry Disability Index (ODI), EQ-5D%, adverse events, X-ray imaging for evidence of radiological loosening, C-reactive protein, and clinical status was collected at baseline, discharge, 6 weeks, 6 months, and 12 months.

After approval for CE registration, the patients were followed for an additional 12 months to collect data on pain scores and identify any potential adverse events. Continuous data below is presented as a mean with the standard deviation (SD) shown in parentheses.

**Results:** Over the period of 7 months commencing September 2017, seventeen patients were recruited (4 Males / 13 Females) with a mean age of 55.6 (13.7) years and BMI of 28.4 (5.4). Data on patients who completed their 24-month review is presented.

Mean scores pre-surgery and at 24-month follow-ups were as follows: for VAS 61.8 (19.2) vs 40.7 (22.5), ODI 48 (18) vs 34.6 (18.3), EQ-5D% 49.9 (21.8) vs 64.8 (20.7). There was no evidence of radiological loosening in any cases reviewed at 12 months, no recorded complication or clinical evidence of local or systemic sensitivity, and no adverse events relating to the implant.

CRP readings were 6.2 (3) pre-surgery, 100.4 (80) at discharge, and 7.2 (5) at 12 months.

**Conclusion:** The findings after 2 years support this implant system to be a safe augmentation to enhance the bone-to-screw interface in spinal surgery. The design of the implant and technique of insertion will be discussed.

## V 72

### Conservative treatment of low back pain in lumbar disc herniation: Comparison of three therapeutic regimens

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**Introduction:** Lumbar disc herniation is one of the most common causes of acute low back pain (LBP). As LBP is associated with low quality of life and various morbidity, proper management should be considered to minimize its health burden (1). Although non-surgical management is considered as the first-line treatment, it has been shown that there is a paucity of well-designed studies to evaluate the optimal conservative management of LBP. Hence, the objective of this study was to compare three therapeutic regimens among patients with acute LBP.

**Methods:** This double-blind randomized clinical trial was conducted during the period of September 2018 to October 2019 in a hospital located in Rasht, Iran. Among 647 patients with acute LBP and confirmed intervertebral disc herniation, 615 (95.0%) patients agreed to participate in the study. All participants were divided into three equal groups by simple randomization. The first group received physical therapy (10 sessions/monthly) and Gabapentin (100 mg/once daily). Other two therapeutic regimens were made by addition of Naproxen (500 mg/twice daily) and Prednisolone (5 mg/twice daily) alongside Naproxen to the first group regimen for the second and third groups, respectively. Oswestry Disability Index (ODI) was used to evaluate functional improvement and daily living of patients at the begging and 12

months after treatment. The analysis conducted with SPSS software version 23 and the significant level set on 0.05.

**Results:** Among all participants, 547 (88.9%) patients completed the study. Generally, 374 (68.3%) were female. The mean (SD) age of study groups were 57.8 (10.5), 55.7 (11.8) and 57.3 (11.2) for the first, second and third group, respectively. Overall ODI score was significantly decreased among all study groups ( $P < 0.001$ ). The between groups analysis revealed significant reduction of ODI score in third group compared to first group ( $P < 0.001$ ) and second group ( $P = 0.04$ ), respectively. There was not significant difference between overall ODI score in first and second groups. Nevertheless, analysis between these two groups showed significant differences among two sections of ODI including pain intensity ( $P < 0.001$ ) and social life ( $P = 0.005$ ).

**Conclusion:** Utilization of low dose corticosteroids and Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) including Naproxen alongside Gabapentin and physical therapy can produce satisfactory clinical results in conservative management of acute low back pain. However, the application of NSAIDs without low dose corticosteroids can only improve pain and following social life of patients and cannot be generally effective.

**References:** Husky MM, Ferdous Farin F, Compagnone P, Fermanian C, Kovess-Masfety V. Chronic back pain and its association with quality of life in a large French population survey. *Health Qual Life Outcomes*. 2018 Sep 26;16(1):195.

## V73

### Supine traction versus prone bending radiographs for assessing the curve flexibility in spinal deformity

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**Goal:** No consensus exists among surgeons on which radiologic method to prefer for the assessment of curve flexibility in spinal deformity. The objective of this study was to evaluate the difference in curve correction on supine traction radiographs versus prone side bending radiographs.

**Methods:** A retrospective analysis of idiopathic scoliosis (IS), degenerative idiopathic scoliosis (DIS) and de novo degenerative lumbar scoliosis (DNDLS) patients was performed on supine traction as well as prone bending films (when available). Age, weight, traction force, diagnosis and Cobb angles of the primary and secondary curves were extracted. Differences in curve correction (percentages) on traction versus prone bending radiographs were analyzed for the primary and secondary curve. Subgroup analyses were performed for the three different diagnoses.

**Results:** In total, 170 patients were eligible for inclusion. 43 were diagnosed with IS, 58 with DIS and 69 with DNDLS. For the primary curve, greater curve correction was obtained with bending in the DNDLS group ( $p < 0.001$ ). In the DIS group, there was a trend towards more correction on bending ( $p = 0.054$ ). In de IS group no difference was found. For the secondary curve, bending showed more curve correction in the IS and DIS group ( $p = 0.002$  and  $p < 0.001$ ). No difference was found in the DNDLS group.

**Conclusion:** In conclusion, bending radiographs compared to traction radiographs better serve the purpose of curve flexibility assessment of IS, DIS and DNDLS spinal deformity, despite the fact that patients are exposed to more radiation.

## V 74

**Comparison of medical quality characteristics in spine surgery based on DWG-Certificate, FOKUS-magazine and Weisse Liste**\*J. Neuhoff<sup>1</sup>, H. Schlag<sup>1</sup>, F. Kandziora<sup>1</sup><sup>1</sup>BG Unfallklinik Frankfurt, Wirbelsäulenchirurgie und Neurotraumatologie, Frankfurt a. M., Germany

**Introduction:** This work compares different quality characteristics of German spine clinics and examines the correlation of the respective characteristics. Quality of medical care may be divided into the dimensions structure, process and outcome quality. In this work number of facilities necessary for spine surgery depicted structure, number of surgical spine treatments depicted process and patient satisfaction/subjective estimation of medical quality depicted outcome quality.

**Methods:** 81 German spine clinics were examined with the aid of data of the "Weisse Liste" of the Bertelsmann foundation. The clinics chosen for investigation were collected by listed clinics with certification of the German spine society (DWG) and the listed clinics of the magazine "FOKUS-Gesundheit" (Top Hospitals 2020, section spine surgery). Data was collected on the public open research platform of "Weisse Liste" (<https://www.weisse-liste.de/de/krankenhaus/krankenhausuche>), which offers data of the structured hospital quality reports and former patient experiences. We compared number of treatments in 2018 within the subsections of spine surgery (three ops- and four ICD-10-Codes), patients' subjective estimation of medical quality and number of facilities necessary for spine surgery in relation to the grading of DWG and FOKUS. Correlation analysis was performed in order to describe relationship with each other.

**Results:** Number of treatments correlated positively with DWG and FOKUS grading (DWG  $r=0.64$ ,  $p<0.05$ ; FOKUS  $r=0.26$ ,  $p=0.07$ ). While patients experience did not directly correlate with DWG or FOKUS (DWG  $r=-0.02$ ,  $p=0.8$ ; FOKUS  $r=-0.12$ ,  $p=0.4$ ), there was a positive correlation between the average number of treatments and positive estimation of medical care between the groups ( $r=0.6$ ,  $p=0.17$ ), though not significant. Number of facilities slightly correlate with DWG grading, but not with FOKUS (DWG  $r=0.2$ ,  $p=1.17$ ; FOKUS  $r=0.007$ ,  $p=0.96$ ).

**Discussion:** First we note that DWG and FOKUS effectively depict structure and process quality. Whereas direct correlation between patients experience and number of treatments is not detectable, higher grading of DWG and FOKUS shows higher average treatment counts and higher average patient satisfaction with a positive correlation. These findings indicate coherence between process and outcome quality as related to German spine surgery.

## V 75

**Acceptance of health apps for quality control, post-market surveillance and post-operative therapy support for spinal surgery patients**\*D. Auerbach<sup>1</sup>, M. Eichler<sup>2</sup>, B. Hölper<sup>2</sup><sup>1</sup>A&S-Engineering GmbH, Geschäftsführung, Fulda, Germany<sup>2</sup>Spine Center Fulda, Fulda, Germany

**Introduction:** Current surveys show a rather negative attitude of patients towards health apps in Germany. However, surveys for studies and quality management can be carried out via digital platforms with patient response e.g. to realize surveys almost automatically using health apps. This allows nationwide data generation in spine surgery which is previously not possible with other known registers. To clarify the acceptance of digital surveys and digital patient information supply e.g. by online videos this study was initiated to interview spinal surgery patients.

**Material and methods:** In a spinal surgery unit, patients were asked about the assessment and acceptance of the use of digital communication platforms over a period of 6 months during the outpatient presentation. After confirmation of the corresponding data protection regulations, the surveys were carried out online by a tablet using an APP (MyBodyPass) and were stored centrally in a secure database. The patients answered questions about their habits of using smartphones, the acceptance of communication via app

with health facilities and manufacturers of medical products. Questions were also asked about the current use of digital medical records and the acceptance of exercise videos and surveys.

**Results:** 120 patients were interviewed, the mean age was 47,3 years. 65% indicated regular smartphone use. 80% of all patients feel comfortable by using digital communicative interaction apps with their treating doctor, 73% with the clinic, 67% with physiotherapy, 65% with their health insurance company and 38% with the medical industry (manufacturer). So far, 3% of respondents have used a digital patient file, 88% file folders and 9% loose sheets. 48% were able to present a data query (surveys) once a day, 32% more often than a data query and 20% would not answer a data query. Exercises per app 41% daily as positive, 49% occasionally and 10% as superfluous. 67% of all patients see their medical care improved, 65% would be willing to pay a financial excess.

**Discussion:** The use of digital communication platforms in patients undergoing spinal surgery shows a predominantly positive response with high acceptance and a great willingness to cooperate. Digital surveys for the purpose of studies, quality management and post-market surveillance can be carried out with a patient acceptance of 80% (in spine surgery) and in the future a comprehensive generation of quality data will play an important role. It is crucial that the surveys are implemented easily and without spending a lot of time. Patients also agree in perceiving digital post-operative therapy support. The decisive factor in acceptance is that the digital surveys via app are proposed by the patient's medical environment, general health apps or applications provided by medical device manufacturers are opposed to the patient.

## V 76

**Intercultural adaptation of the SOSGOQ2.0 questionnaire into a German version and it's multicentric validation**\*W. Kisel<sup>1</sup>, T. Datzmann<sup>2</sup>, J. Kramer<sup>1</sup>, M. Dreimann<sup>3</sup>, J. D. Müller-Broich<sup>4</sup>, C. Netzer<sup>5</sup>, K. D. Schaser<sup>1</sup>, A. C. Disch<sup>1</sup><sup>1</sup>Universitätsklinikum Carl Gustav Carus Dresden, UniversitätsCentrum für Orthopädie und Unfallchirurgie, Dresden, Germany<sup>2</sup>Universitätsklinikum Carl Gustav Carus Dresden, Zentrum für Evidenzbasierte Gesundheitsversorgung, Nationales Center für Tumorerkrankungen Dresden, Dresden, Germany<sup>3</sup>Universitätsklinikum Hamburg-Eppendorf, Zentrum für Operative Medizin, Klinik und Poliklinik für Unfallchirurgie und Orthopädie, Hamburg, Germany<sup>4</sup>Orthopädische Universitätsklinik Friedrichsheim, Frankfurt a. M., Germany<sup>5</sup>Universitätsspital Basel, Spinale Chirurgie, Basel, Switzerland

**Introduction:** Patients with malign tumors continuously benefit from a better and longer disease control (Quaresma et al., 2015) but have in turn a higher risk for spinal metastases. In a palliative situation, health related quality of life (HRQOL) is coming more into focus. The Spine Oncology Study Group Outcomes Questionnaire (SOSGOQ) was proven to be a valid and reliable instrument measuring HRQOL in native English speaking patients suffering from spinal malignancies (Street et al., 2010). A German version was not available, yet. The goal of this study is to interculturally adapt and apply this tool in German speaking patients.

**Material/Methods:** Following consent of the Knowledge Forum (KF) Tumor of the AOSpine an intercultural adaptation of the SOSGOQ2.0 was performed according to the guidelines published by Beaton (Beaton et al., 2000). In a multistep translation and re-translation process the SOSGOQ2.0\_GER was developed. Reliability is measured at two different days, at the same day time, within a week, without a therapeutic intervention in between (t1, t2). A further assessment followed 4 weeks after t1 (t3). Furthermore the tool was tested in comparison to the generic EORTC QLQ-C30 questionnaire (Sprangers et al., 1993) for overall and domain-specific (physical-, social-, mental functioning, pain) external construct validity. (Cronbachs alpha, Inter-Item correlation, ROC curve analysis).

**Results:** In this multicenter study 51 male and 53 female patients were recruited. Average age was 65.5 ( $\pm 11.1$ ) years, average performance status ECOG graded 1.98 ( $\pm 0.99$ ). Most frequent tumors were metastases of the prostate ( $n=20$ ), breast cancer ( $n=14$ ) and spinal lesions of multiple myeloma ( $n=13$ ) followed by other malignancies ( $n=57$ ). Treatment was intended in 77 patients palliatively, in 13 curatively and in 15 unclearly. Test-reliability for the SOSGOQ2.0\_GER questionnaire was approved by the TOST-method (two one-sided t-tests) (Lakens, 2017) (first 20 patients reaching  $t_2$ ,  $p=0.05$ ,  $\alpha=0.1$ ). 89 patients were considered in the preliminary statistical analysis. An excellent external construct validity in comparison to the EORTC QLQ-C30 questionnaire was approved for the overall construct and the single domains (physical-, social-, mental functioning, pain). The Bland-Altman method ( $p=0.05$ ,  $\alpha$ -error 10%, power 80%) was used to compare both measurement instruments regarding their agreement in measuring HRQOL. All comparisons were within the predetermined limits of 10% error (in fact mostly  $< 5\%$ ).

**Discussion:** The SOSGOQ2.0\_GER-questionnaire is a reliable and valid tool to measure HRQOL. According to our results this tool can be highly recommended for future studies and versatily applied in German speaking patients with malign tumors of the spine.

## V 77

### Adverse Events and Human Performance Deficiencies in Spinal Surgery at an Academic Neurosurgery Department

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**Introduction:** Adverse events (AE) in surgery are a relevant cause of disability or death. The frequency of AE is a key quality indicator that plays an important role in the future of health care, especially in surgery. The implementation of quality management and systems-based solutions in surgical care, such as checklists or standard operating procedures, has improved patient safety. However, potentially avoidable patient harm has persisted. Little is known about the role of human error in spinal surgery. This study aims at quantifying the frequency and severity of AE and the contribution of human error to AE in spinal surgery at a supra-maximum medical care center.

**Methods:** This is a prospective study including all patients undergoing spinal surgery at our department. All AE per case (within 30 days of surgery) are identified and classified according to the American College of Surgeons (ACS) and the Spine Adverse Events Severity System (SAVES-V2 grades 1-6) by consensus of all senior surgeons of our department. In addition, human error in AE is identified and classified using a human performance deficiency (HPD) classifier published by Suliburk et al. HPDs are assigned to 5 major categories: planning or problem solving, execution, rules violation, communication, and teamwork.

**Results:** During 6 months, 136 out of 730 cases (18.6%) had one AE or more. The total number of AE was 151 (1-3/case). Multiple AE occurred in 2% of cases. The risk for AE did not increase after the first AE.

Most AE occurred during (46.3%) or after (46.4%) surgery. The most frequent ACS types were iatrogenic surgical injury (37.1% of all AE), neurological deficit (13.2%), unplanned return to OR (12.6%), and wound events (11.9%). Most AE had medium or low severity (SAVES grade 3: 45.5% of all AE; grade 2: 29.5%; grade 1: 6.1%). However, the frequency of severe AE was substantial: 18.9% of all AE were either grade 4 (6.8%), 5 (5.3%) or 6 (6.8%; corresponding to 1.4% mortality).

Almost half (47.1%) of AE were associated with human error. The most frequent HPD class was execution (mostly technical errors during surgery) with 26.9% of all AE. 17.3% of all AE were planning or problem solving errors. Rules violation and teamwork accounted for 1.9% and 1.0% of all AE. There was no communication error.

**Discussion:** We found that AE occur frequently (18.6%) in spinal surgery at a supra-maximum medical care center. This may appear to be higher than expected when compared to typical complication rates

reported in surgical case series. However, our data was collected prospectively, and our case mix includes high proportions of complex and multimorbid patients.

It is important to realize that AE occur frequently not only when discussing with the patient, but also when discussing quality-based accreditation and reimbursement in upcoming health care reform.

Of note, the high frequency of HPD in AE shows that there is still potential to further eliminate avoidable patient harm.

## V 78

### Clinical efficiency of sliding gantry CT-based as compared to mobile cone-beam CT-based navigated pedicle screw placement – an observational cohort study on 853 patients and 6733 screws

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**Introduction:** Today, multiple solutions for navigation-guided pedicle screw placement are available. For the present study, we analyzed the efficiency of a sliding gantry CT-based (SGCT) and a mobile cone-beam CT-based (CBCT) approach for spinal instrumentation.

**Methods:** We retrospectively analyzed all patients who underwent SGCT-based or CBCT-based pedicle screw placement for spinal instrumentation at our department between 11/2015 and 01/2020.

**Results:** Intra- and postoperative complications did not differ between the two groups. Although the accuracy of screw placement according to Gertzbein-Robbins classification did not differ between the two groups, more screws had to be revised intraoperatively in the CBCT group (SGCT: 98, 2.8% vs. CBCT: 128, 4.0%;  $p=0.0081$ ).

The median time of patients inside the operating room (*Entry – Exit*) was significantly shorter for the SGCT group (SGCT: median, [95% CI] 237.5, [247.8, 264.3] min, CBCT: 267, [274.4, 291.5] min;  $p<0.0001$ ) based on shorter times for *Positioning – Incision* (SGCT: 17, [18.1, 19.9] min, CBCT: 32, [32.2, 35.5] min;  $p<0.0001$ ) and *Suture – Exit* (SGCT: 22, [23.6, 26.1] min, CBCT: 25.5, [27.5, 30.7] min;  $p<0.0001$ ).

**Conclusion:** The present results show that the choice of assistive technology for navigated pedicle screw placement has significant impact on standard spine procedures even in a high-volume spine center. Particularly with regard to cost-effectiveness and the duration of surgeries, the shorter time needed for preparation and positioning in the SGCT group made the main difference, while the quality of accuracy was even higher.

## V 79

### Automated Screw Planning of Navigated Lumbosacral Pedicle Screws Using Artificial Intelligence

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**Introduction:** Use of navigation for insertion of pedicle screws has gained traction in recent years and has been shown to reduce radiation exposure while improving screw placement accuracy. However, preoperative planning of screw dimensions and trajectories is a time-consuming but necessary task in order to tap the full potential of this technique. The aim of this study was to develop and validate a software tool for automated planning of lumbosacral pedicle screws using artificial intelligence (AI).

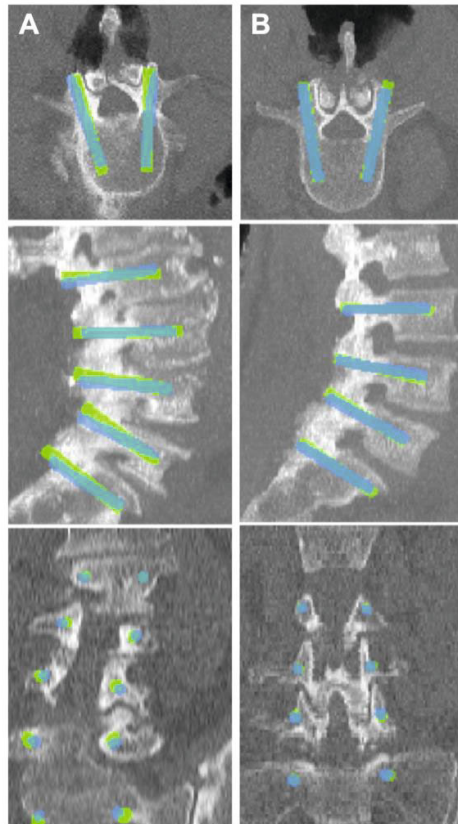
**Methods:** We used planning data from random 155 CT-navigated instrumentations from a single academic institution and extracted screw parameters from 1052 pre-planned pedicle screws covering L2-S1 levels. 3D lumbar CT and screw parameters served as training data to develop a planning algorithm for pedicle screws based on a convolutional neural network. A vertebra instance-based approach employing a state-of-the-art U-Net framework was

developed and trained followed by internal 5-fold cross-validation. The retrieved net was evaluated on an external test-set of 30 cases not involved in training. On lumbar CT, screw parameters were automatically derived from the predicted screw masks using connected component and principal component techniques for a total of 198 screws. Screw parameters were compared to corresponding pre-planned screws in the test-set by mean absolute difference (MAD) of screw head and tip points, length and diameter, respectively. Clinical acceptability of algorithm-generated screws was evaluated by experts using the Gertzbein-Robbins (GR) classification.

**Results:** Automated planning was feasible for all targeted 198 screws covering levels L2-S1 (n=18, 42, 52, 52, 34 screws, respectively). Average computational time was  $2.9 \pm 0.35$  sec per vertebra. Compared to pre-planned screws, MAD was  $4.3 \pm 2.1$  mm for screw head,  $4.2 \pm 2.4$  mm for tip points,  $4.6 \pm 3.1$  mm for length and  $0.4 \pm 0.3$  mm for diameter. In ANOVA followed by Dunn's multiple comparison, MAD for head and tip points was significantly greater at L5 and S1 compared to other segments ( $p < 0.001$ ), reflecting increasing degrees of freedom in caudal screw placement. No difference between segments was found for screw length and diameter. Upon expert rating, screws were predominantly classified grade A (189, 95%) with only 9 grade B screws (5%) according to GR indicating that screws showed either no, or only minor ( $< 2$  mm) cortical breach, respectively. All planned screws were classified clinically acceptable. **Fig. 1** shows automatically obtained screws (blue) and manually pre-planned screws (green) for two illustrative cases (A, B).

**Conclusion:** We derived a fully automated planning tool for lumbosacral pedicle screws using AI. Validation showed sufficient accuracy to facilitate screw planning with high potential to increase time-efficiency in navigated spinal instrumentation when integrated into commercial navigation systems. Extension of functionality to encompass thoracic and cervical screws is underway.

**Fig. 1**



## V 80

### Procedural metrics for minimally invasive lumbar stenosis decompression using a lumbar stenosis simulation model to improve the skills and accelerate learning curve in orthopedic and neurosurgical trainees

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**Background:** Surgical training should enable a surgeon to acquire the theoretical and practical knowledge necessary to perform a designated surgical procedure skillfully, reliably, and safely.

**Purpose:** To prove concept of operationally defined metrics for a minimally invasive unilateral laminotomy for bilateral decompression (ULBD) for lumbar spinal stenosis and quantify the educational benefit of using a state-of-the-art spine surgery simulation lumbar stenosis model to improve the skills of orthopedic and neurosurgical residents by evaluating their performances in specific surgical tasks and comparing surgical outcomes over time.

**Methods:** In a prospective comparative study simultaneously performed at 2 centers, one in the US (Neurosurgery) and one in Germany (Orthopedic surgery) 6 trainees from each center performed three identical decompression procedures on a spinal simulator using the metrics for ULBD. The learning curve was evaluated regarding technical skills, timing, occurrence of errors using instructor and personal surveys as well as a gap analysis. Furthermore, video recordings of all procedures were rated by 3 individual experts using a global rating scale and a video specific checklist.

**Results:** Within all residents the quantity of errors and sentinel errors were significantly reduced from procedure 1 to procedure 3 with a concomitant reduction of surgical time and skipped steps. Furthermore surgical skills were improving significantly showing economy of motion using the right instruments in a natural progression of the surgery. This was confirmed by the instructor as well as the attendee and 3 independent experts rating the videos.

**Conclusions:** Procedural metrics for ULBD in combination with a surgical simulator can be successfully used in surgical training to improve the surgical skills of orthopedic and neurosurgical residents.

## V 81

### Pharmacokinetics of Cefuroxime in Spine

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**Question** Spondylodiscitis is a rare but feared complication in orthopaedic surgery. Therefore, patients undergoing spine surgery are usually pretreated with cefuroxime before surgery to reduce the incidence of peri- or postoperative infections. In our study, we tried to answer the question if the concentrations, reached in vertebral body and intervertebral discs, are high enough to protect against a bacterial infection. To the best of our knowledge, this is the first study to assess the kinetics of vertebral bodies and intervertebral discs and to correlate this with plasma concentration of cefuroxime in human patients using population kinetics.

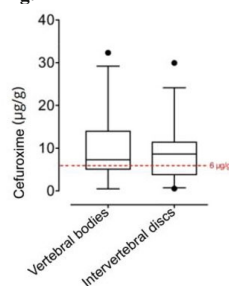
**Material/Methods** We studied plasma population kinetics and bone and intervertebral disc (C5/6 till L5/S1) concentrations of cefuroxime in orthopaedic patients (22 male and 18 female) treated intravenously by a single bolus injection with cefuroxime (1.5 g) prior to operation. Blood samples were drawn before and at eight time points (about hourly) after cefuroxime infusion. After surgical removal, extracts of bone samples, intervertebral discs and plasma samples were prepared, and cefuroxime was quantified in these extracts as well as in plasma using high performance liquid chromatography (HPLC). Plasma kinetics was analyzed using a population approach (ADAPT 5)

**Results** Cefuroxime concentrations in vertebral body and intervertebral discs were calculated as  $9.6 \pm 1.3 \mu\text{g/g}$  and  $8.9 \pm 1.1 \mu\text{g/g}$ , respectively. The mean concentrations of cefuroxime in the intervertebral discs were not different from the concentrations in the vertebral bodies. All plasma samples achieved concentrations above a threshold of  $6 \mu\text{g/ml}$ , usually required for sufficient antibiotic protection.

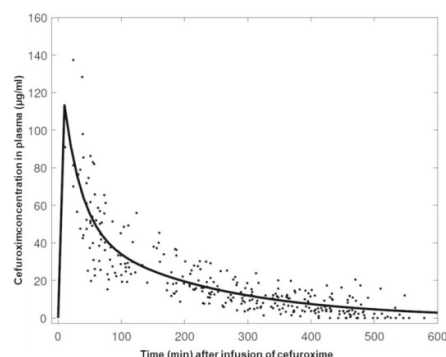
This threshold was not achieved in 14 intervertebral discs ( $n=35$ ) and in 12 intervertebral bodies ( $n=32$ ).

**Conclusion** Under the conditions of our study, not all patients benefited from perioperative antibiotic prophylaxis with 1.5 g cefuroxime. The concentrations of cefuroxime reached in the vertebral bodies and intervertebral discs probably cannot always protect the patients against typical cefuroxime-sensitive nosocomial infections (taking  $6 \mu\text{g/ml}$  of cefuroxime as breaking point for germs). Higher concentrations of cefuroxime are probably needed or different antibiotics should be chosen.

**Fig. 1**



**Fig. 2**



## V 82

### Diffusion weighted magnetic resonance imaging for the diagnosis of patients with lumbar nerve root entrapment syndromes

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**Introduction** Lumbar nerve root entrapment syndromes are a frequent cause of radicular syndromes of the lower extremities. Diffusion-weighted (DWI) imaging is a MRI based imaging technique, that allows visualizing movements of water molecules in nerve tissue. Eguchi et al. [1] found out that the lumbar nerve root pathology can be successfully diagnosed with this method. The purpose of this study was to determine the value of DWI MRI technology for the diagnosis of patients with symptomatic lumbar nerve root entrapment syndromes in a larger patient collective. For this purpose we compared the results from healthy, asymptomatic volunteers from the pilot study of Reinhold et al. [2] with symptomatic patients suffering from radicular L4-S1 symptoms.

**Methods:** 40 patients were prospectively allocated to either one of two groups. Group 1= 20 patients with lumbar disk herniations (average age 55 years,  $n=16$  male,  $n=4$  female) and group 2= 20 with degenerative neuroforaminal stenosis (average 70 years,  $n=10$

male,  $n=10$  female). A diffusion weighted spin-echo type echo-planar (SE-EPI) sequence was used to determine axial ADC values of dorsal root ganglion (DRG) and added to the standard MRI protocol (1.5T Magneto Aera, Siemens Healthcare GmbH, Rostock, Germany).

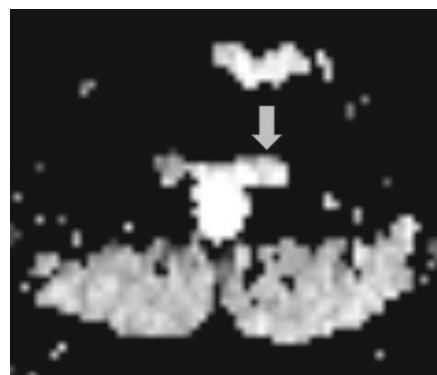
**Results:** All DRG could be visualized and measured on axial images. Statistical significant differences were found between ADC values of healthy volunteers (median  $1171.25 \text{ mm}^2/\text{s}$ ) and symptomatic patients ( $1543.667 \text{ mm}^2/\text{s}$ ) ( $p<0.001$ ). The ADC-values in group 1 were represented by a "brighter" appearance based on the nerve root pathology (Fig. 1). Furthermore, we saw a statistically significant difference between the average ADC values from the asymptomatic ( $1520.929 \text{ mm}^2/\text{s}$ ) and symptomatic ( $1618.314 \text{ mm}^2/\text{s}$ ) side ( $p=0.019$ ), especially by looking at the two groups is that of disc herniations highly significant ( $p=0.002$ ).

**Discussion:** Our results have confirmed the preliminary data of Eguchi et al. [1] within a larger patient collective. DWI-MRI can be helpful and used in a routine fashion for the diagnosis of patients with lumbar nerve root entrapment syndromes with a standard MRI scanner in a community hospital.

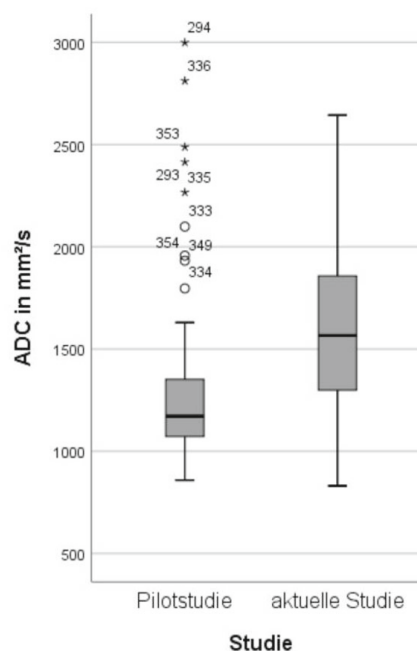
**References:** 1. Eguchi et al (2010) 19(11):1874–1882. doi: 10.1007/s00586-010-1520-9

2. Reinhold et al (2015) 24(2):319–326. doi: 10.1007/s00586-014-3602-6

**Fig. 1**



**Fig. 2**



## V 83

**Effect of standardized Pain Neuroscience Education in Interdisciplinary Multimodal Pain Therapy on current pain.**\*M. Richter<sup>1</sup>, C. Rauscher<sup>2</sup>, J. Mallwitz<sup>3</sup>, A. Kluttig<sup>4</sup>,K. S. Delank<sup>5</sup><sup>1</sup>Rückenzentrum Am Michel, Physiotherapie Am Michel GmbH, Hamburg, Germany<sup>2</sup>Asklepios Klinikum St. Georg, Hamburg, Germany<sup>3</sup>Rückenzentrum Am Michel, Praxis für Orthopädie, Hamburg, Germany<sup>4</sup>Martin-Luther-University, Institute for Medical Epidemiology, Biometrics and Informatics, Interdisciplinary Center for Health Sciences, Halle a. d. S., Germany<sup>5</sup>Universitätsklinikum Halle, Halle a. d. S., Germany

**Background:** Interdisciplinary multimodal pain therapy (IMPT) programs for chronic back pain are effective. The patient centered and biopsychosocial nature of IMPT is grounded in contemporary understanding that chronic pain states reflect heightened sensitization of the nervous system rather than an issue in the tissue. Teaching patients about pain is part of IMPT programs, though a clinical guideline is lacking. Does the implementation of a standardized pain neuroscience education (PNE) lecture for patients, into an IMPT program, produce superior results then the IMPT program itself?

**Method:** An intervention study was performed with 179 patients indicated for IMPT. Intervention group (N=102) received a four-week IMPT, which contained additional 4 one hour sessions PNE. Control group (N=77) started the same IMPT before the intervention group and received no additional PNE. Primary outcome was current pain. Pain knowledge, physical function, depressive symptoms, anxiety, stress, quality of life and fear were analyzed as secondary outcomes. Outcomes were defined as change of the parameter measured before and after the IMPT. For each outcome, linear regression models were used to estimate the raw and adjusted effect of additional PNE.

**Results:** Despite improvement in all outcomes for both groups during the treatment phase, the implemented PNE did not result in additional pain reduction (regression coefficient for PNE-effect on pain-level 0.34; 95% CI -6.23 – 6.97). Between group differences could only be shown for pain related knowledge in favor for the intervention group (0.78; 95% CI 0.35 – 1.20).

**Conclusion:** The additional PNE lecture did not lead to pain reduction beyond the usual IMPT.

## V 84

**Increased Lumbar Fusion by a Novel Pro-osteogenic Small Molecule – Preclinical Evaluation in a Rat Model**L. Findeisen<sup>1,2</sup>, C. Vater<sup>1,2</sup>, J. Bolte<sup>1</sup>, L. Straßburger<sup>1,2,3</sup>, L. M. Matuszewski<sup>1,2</sup>, D. B. Raina<sup>4</sup>, A. C. Disch<sup>1</sup>, \*S. Zwingenberger<sup>1,2</sup><sup>1</sup>Universitätsklinikum Carl Gustav Carus an der Technischen Universität Dresden, UniversitätsCentrum für Orthopädie und Unfallchirurgie, Dresden, Germany<sup>2</sup>Universitätsklinikum Carl Gustav Carus an der Technischen Universität Dresden, Zentrum für Translationale Knochen-, Gelenk- und Weichgewebeforschung, Dresden, Germany<sup>3</sup>Universitätsklinikum Carl Gustav Carus an der Technischen Universität Dresden, Abteilung für Plastische und Handchirurgie, UniversitätsCentrum für Orthopädie und Unfallchirurgie, Dresden, Germany<sup>4</sup>Lund University, Faculty of Medicine, Department of Clinical Sciences Lund, Orthopedics, Lund, Sweden

**Introduction:** Autologous bone grafting is still the gold standard to support lumbar spinal fusion surgeries. However, the development of pro-osteogenic graft substitutes is aimed to accelerate fusion rates and reduce donor site comorbidities.

The pro-osteogenic potential of a novel potent small molecule (KMN-159) was investigated by using mineralized collagen matrix (MCM) scaffolds as carrier in a posterolateral spinal fusion rat model. KMN-159 is a novel, highly selective prostaglandin-receptor (EP4) agonist. We hypothesized that KMN-159 would lead to a dose-dependent increase of bone volume comparable to

bone morphogenetic protein 2 (BMP-2) without inducing negative side effects.

**Materials/ Methods:** This *in vivo* study was performed on 144 10-week-old male Wistar rats. According to the implant, rats were randomized into 6 groups (n = 12): 1) negative control, no scaffold (SHAM), 2) scaffold only (MCM), 3) positive control, MCM + 20 µg BMP-2, 4) – 6) MCM + 20, 200 or 2000 µg KMN-159. All experiments were performed in adherence to the National Institutes of Health Guidelines for the Use of Experimental Animals and were approved by the Local Animal Care Committee (protocol no. 25-5131/474/38). Native or BMP-2/KMN-159-functionalized scaffolds were implanted bilaterally onto the transverse processes of L4 and L5 with fixing the implant by adapting the soft tissue around it. To analyze fusion rates, animals were observed for 3 and 6 weeks, respectively. Then, animals were euthanized, and X-ray was performed on the explanted, operated vertebral bodies to grade the fusion. Radiographic grade of fusion was scored 1 (no fusion) to 3 (complete fusion). Additionally, microcomputed tomography (µCT)-scans of 25 µm voxel size were done to analyze the regenerated bone volume. For histomorphological investigations, Masson Goldner staining was performed on all 3-week specimens. The histological grade of fusion was evaluated using a scale ranging from 0 (empty islets) to 7 (complete bony fusion). Kruskal-Wallis test was used for statistical analysis between the groups. Differences were considered significant when  $p < 0.05$ .

**Results:** All animals survived the surgeries and the observation periods. µCT evaluation of the intertransverse bone volume showed a significant increase when the scaffolds were functionalized with BMP-2 and 2000 µg of KMN-159. In line with this, radiographic and histological grading revealed a significantly higher fusion score for the KMN-159 and BMP-2 groups compared to SHAM and MCM group.

**Discussion:** With respect to bone volume and grade of fusion 2000 µg of the novel small molecule KMN-159 was as sufficient as 20 µg BMP-2 in a posterolateral spinal fusion rat model. This might constitute as a beneficial alternative to autologous bone or BMP-2 considering side effects and comorbidities.

Fig. 1

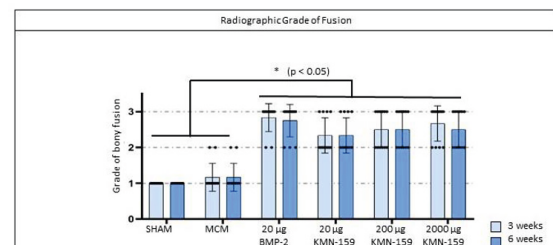
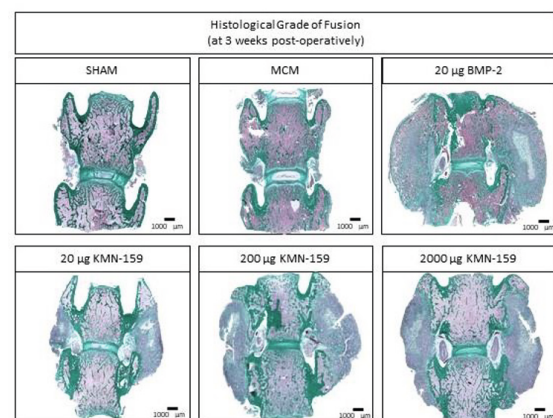


Fig. 2



## V 85

**Suitability of cytokines for the discrimination of vertebral osteomyelitis and degenerative diseases of the spine**J. Brinkmann<sup>1</sup>, J. S. Scharrenberger<sup>1</sup>, E. C. Zeißler<sup>1</sup>, M. Majjouti<sup>1</sup>, \*M. J. Scheyerer<sup>2</sup>, A. Yagdiran<sup>2</sup>, N. Jung<sup>3</sup>, J. Siewe<sup>4</sup>, E. Mahabir-Brenner<sup>1</sup><sup>1</sup>Center for Molecular Medicine, University of Cologne (CMMC), Köln, Germany<sup>2</sup>Universitätsklinikum Köln (AöR), Klinik und Poliklinik für Orthopädie und Unfallchirurgie, Köln, Germany<sup>3</sup>Universitätsklinikum Köln, Klinik I für Innere Medizin, Köln, Germany<sup>4</sup>Klinikum Leverkusen, Leverkusen, Germany

**Introduction:** Vertebral osteomyelitis (VO) is an infection of the intervertebral discs, which progresses slowly and destroys the vertebral bodies. Diagnosis is often delayed due to unspecific symptoms and a lack of specific infection markers. Prospective data to optimize the diagnosis of VO are scarce. In this study, we determined the suitability of cytokines for the discrimination of VO and degenerative diseases of the spine and also compared its diagnostic potential to the use of CRP.

**Material & Methods:** This is a prospective single-center case-control study with the inclusion of patients from 2015 to 2017 who were diagnosed with VO in our hospital based on clinical, radiological, and microbiological criteria. The patients recruited underwent surgical stabilization of the lumbar and/or thoracic spine in combination with removal of one or more affected intervertebral discs, either as therapy for VO (infected group, n = 16 patients) or for erosive osteochondrosis (control group, n = 20 patients). Blood was drawn at five timepoints from each patient: before surgery (pre-OP) and after surgery (post-OP: 3–5 days, 6–11 days, 40–56 days, and 63–142 days). The CRP level was determined via latex agglutination assay. In total, 27 cytokines were measured via ELISA in a multiplex analyzer.

**Results:** A significantly higher CRP concentration was found in the VO patients pre-OP (23.2-fold) and 6–11d post-OP (2.2-fold) compared to the control patients. Significant changes in 6 cytokines at different intervals were observed in the VO patients; pre-OP: IL-6 (22-fold), IL-8 (1.5-fold), IL-12 (1.9-fold), and VEGF (2.8-fold), 3–5d post-OP: IL-12 (2.2-fold), 6–11d post-OP: IL-4 (0.8-fold), IL-12 (1.5-fold), and RANTES (0.8-fold), 40–56d post-OP: IL-8 (1.4-fold) and RANTES (0.8-fold). For the pre-OP interval, there was a significant strong correlation with the CRP values and VEGF in the VO patients as well as with G-CSF and IL-8 in the control patients. The majority of strong correlations between the cytokines and CRP were found at post-OP stages of the study. For the pre-OP interval, CRP (0.9125, 95% CI:0.797–1.000) and the 4 cytokines, IL-6 (0.9750, 95% CI:0.935–1.000), IL-8 (0.8625, 95% CI:0.732–0.993), IL-12(p70) (0.813, 95% CI:0.655–0.971), and VEGF (0.8679, 95% CI:0.749–0.986) showed an area under the curve > 0.80.

**Discussion:** This is the first prospective study in which a broad spectrum of 27 cytokines was analysed via multiplex assay using sera from patients with and without VO. Our results show that, in addition to CRP, 6 different cytokines were significantly altered during the study. From these, IL-6, IL-8, IL-12, and VEGF were significantly elevated prä-OP, implicating that they may be used in a multiplex assay for discrimination between VO and degenerative diseases of the spine.

## V 86

**The "unfair advantage" of hybrid spine surgery simulation for percutaneous pedicle screw placement makes it as effective as training on a cadaver: a prospective randomized study with novice volunteers**\*S. Weidert<sup>1</sup>, J. Bischoff<sup>1</sup>, C. A. Becker<sup>1</sup>, C. Kammerlander<sup>1</sup>, A. Greiner<sup>1</sup>, M. Mayr<sup>1</sup>, W. Böcker<sup>1</sup><sup>1</sup>LMU Klinikum München, Klinik für Allgemeine, Unfall- und Wiederherstellungschirurgie, München, Germany

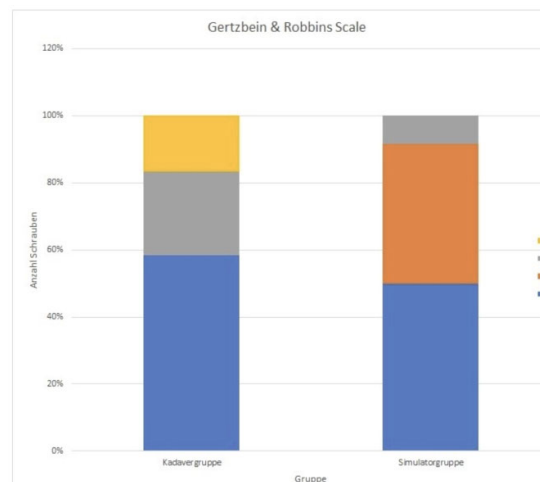
Learning percutaneous pedicle screw placement requires the acquisition of many skills such as correct adjustment of the c-arm, locating the bony entry point and advancing the trocar using the projection images. The recommended gold standard training model is the cadaver. Its disadvantages are availability, cost and radiation dose. A hybrid simulator co-developed at the LMU uses a clever combination of 3D printed specimens with virtual imaging to train these skills.

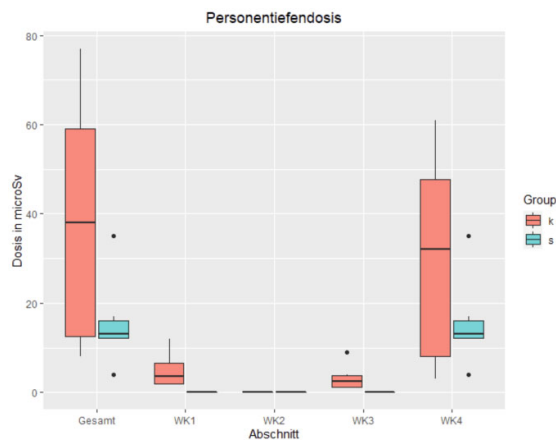
**Objective:** A study will investigate the hypothesis that the simulator can be used to learn the skill of percutaneous pedicle screw placement as effectively as with the cadaver and real imaging.

**Methods:** The hybrid simulator consists of a torso with exchangeable spinal segment. The instruments are electromagnetically tracked and the software can generate x-rays in all projections as well as CT and 3D images. The study design is a randomized prospective study with a simulator group and a control group at the cadaver. The study was divided into a training day followed by a test day. Initially, theoretical training was given in a common seminar format. While the control group was then intensively trained in teams of two on the cadaver itself by an experienced surgeon, the simulator group initially received only peer-teaching on the simulator. On the test day, the simulator group was trained by the expert in the form of 30 minutes of individual instruction. All participants then implanted 2 percutaneous pedicle screws on the cadaver without further assistance. After each session, a CT was performed and the screw positions were evaluated.

**Results:** 12 medical students were randomized to equal groups. All participants completed the training and test day. The main outcome parameter quality of pedicle screw placement was evaluated on CT according to Gertzbein-Robbins (GR). The simulator group achieved GR A or B (under 2mm pedicle breach) in 93% of cases, the control group only in 58%. The stat. significance was slightly missed with p=0.059. With regard to time, there was a tendency towards superiority of the simulator group, whose measured personal dose was significantly reduced over both days.

**Discussion:** The simulator group showed no inferiority but a clear tendency towards superior performance. Especially compared to day 1 of the control group, a strong effect of the simulator on skills is measurable. This is probably due to the "unfair advantage" of the constant availability (training immediately before the "real intervention" is possible), the repeatability as well as the visualization (to train projection thinking) and realistic haptics of the simulator. At least for the learning of percutaneous pedicle placement, the simulator is at least an equivalent substitute for cadaver training.

**Fig. 1****Fig. 2**



### SP 1

#### The impact of the COVID-19 pandemic on spine surgery in central Europe

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**Introduction:** The SARS-CoV2 crisis led to many restrictions in daily life and protective health-care actions in all hospitals to ensure basic medical supply. Thus, medical care was reduced to a minimum, so that only emergencies were treated in many hospitals. This questionnaire-based study among spinal surgeons in central Europe was generated to examine the impact of COVID-19 and consecutively the differences in restrictions in spinal surgery units.

**Material & Methods:** An online survey consisted of 32 questions on the impact of the COVID-19 pandemic and the performed preventions and restrictions of spinal surgery units was created. Surgical fellows and consultants from neurosurgical, orthopedic and trauma surgical departments were included in our questionnaire-based study with the help of DWG, DGNC, ÖGNC, ASS, SGNC & SGS.

**Results:** In a total of 406 completed questionnaires, the majority of participants reported of increased preventive measurements at daily clinical work ("split-team" work schedule [44%], cancellation of elective and/or semi-elective surgeries [91%], random or systemic sample SARS-CoV2 testing for medical staff [23%]), reduced occurrence of emergencies (91%), decreased out-patient work (45%) with increased telemedical care (73%) and a reduced availability of medical equipment (75%) as well as medical staff (30%). While the majority of physicians considered the political restrictive decisions to be not suitable, most considered the medical measures to be appropriate.

**Discussion:** The results of this study showed comparable restrictive measures for spinal surgical departments in central Europe. In the majority of cases, departments with COVID-19 patients led to a decrement of elective surgical interventions to a minimum while concentrating on providing additional resources reserved for SARS-CoV2-positive patients. While major restrictions were introduced in the majority of the participants' department, the supply of PPE as well as the outpatient care remained insufficient and should be evaluated intensively for future global healthcare events.

### SP 2

#### Biomechanics of the Transverse Atlantal Ligament in elderly specimens in a more physiological model

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**Introduction:** The transverse ligament is the strongest ligament of the craniocervical junction and therefore, plays a critical role in atlanto-axial stability. However, several clinical studies have questioned this ligament's strength in the elderly. The goal of this cadaveric study was to reevaluate the force required for the transverse ligament to fail in a more physiological biomechanical model in elderly specimens.

**Material/Methods:** Twelve C1-2 specimens were harvested from fresh-frozen Caucasian cadavers with a mean age at death of 81 years (range 68–89 years). Only the transverse ligament was preserved, and the bony C1-2 complex was left intact. The dens was pulled away from the anterior arch of C1 using a strength test machine that applies controlled increasing force. After testing, the axis was split in half to check for hidden pathologies and osteoporosis. The differences in the failure force between sex and age groups (group 1: < 80, group 2: > 80 years) were compared.

**Results:** The mean force required for the transverse ligament to fail was  $236.2 \pm 66$  N (range 132–326 N). All but two specimens had significant osteoporotic loss of trabecular bone. No significant differences between sex and age groups were found.

**Discussion:** The transverse ligament's failure in elderly specimens occurred at an average force of 236 N, which was lower than that reported in the previous literature. The ligament's failure force in younger patients differs and may be similar to the findings published to date.

### SP 3

#### PEEK cages versus Titanium coated PEEK cages in single level anterior cervical fusion – a randomized controlled study

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#### Introduction/Aim

The implantation of a spacer is a common practice after anterior discectomy in cervical spine. Polyether-Ether-Ketone (PEEK) cages have replaced Titanium implants due to their better radiological visibility and appearance in postoperative MRI-scans. However they earned poor reputation due to apparently higher nonunion rates. The aim of the study was to evaluate the fusion behavior of plain PEEK cages in comparison to Titanium coated PEEK (TiPEEK) cages.

**Materials and Methods:** We randomized 104 patients with single level cervical radiculopathy or mild myelopathy and divided them into two groups of 52 patients each, receiving either a PEEK Cage or the Titanium coated variant of the same Cage type. The implantation was performed without additional filling of the cage with fusion material. Obese patients (BMI over 35kg/m<sup>2</sup>), Aspirin users as well as smokers were excluded from the study. The 1- and 2-year follow ups were completed by 43 patients in the PEEK group and 50 in the TiPEEK group. The baseline statistics showed no differences. The male/female ratio in the PEEK group was 18/25 and in the TiPEEK group 23/27. The mean age at the time of surgery was  $49.7 \pm 12$  years (range: 29–78) in the PEEK group and  $48.3 \pm 11.7$  years (range: 29–70) in the TiPEEK group, respectively. The body mass index (BMI) was  $25.7 \pm 4$  in the PEEK and  $26.5 \pm 4.2$  in the TiPEEK group. Fusion was determined by plain X-ray and lateral functional X-ray. All images were reviewed by an independent experienced radiologist. For the clinical presentations the cervical NASS Score was used. At each clinical visit all patients had to evaluate their neck and arm pain by using the Visual Analogue Scale (VAS). The study was approved by the ethics committee of the State Medical Association.

**Results:** After 6 months 2 cases in each group showed early fusion. Follow up after 1 year showed a fusion in the radiological images for 15 cases of the PEEK group and in 22 cases of the TiPEEK group. At the endpoint of the study after 2 years in 37 patients of the PEEK group (86%) a complete fusion was observed. Six cases were considered as non-unions. In the TiPEEK group we found 41 fusions (82%) and 9 non-unions at this time. The difference was calculated to be not

significant ( $p=0.59$ ). The clinical evaluation the two groups showed no difference in the neurological examination or the pain scores over the time.

#### Conclusion

Despite some assumptions about an advantage of TiPEEK over PEEK cages for fusion in spine surgery, this prospective randomized controlled study did not show an accelerated or improved fusion with TiPEEK after anterior cervical discectomy. The clinical results and the outcome were favorable in this selected patient group (age, BMI etc.) regardless of which implant material was used.

#### SP 4

##### Determinants for spinal surgery

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**Introduction:** In Germany a persistently high regional heterogeneity in the frequency of spinal surgery is present, which cannot be explained by the age structure of the population. Therefore, the question arises which determinants at the patient level have an influence for and against an invasive intervention and which differences in the health care system might have caused them.

**Methods:** Based on nationwide anonymized AOK routine health care data, all insured persons with residence in Germany and spine diseases (ICD-10 diagnosis M40-M54) without spinal fractures in the period 2008 to 2016 (18.4 million persons) were used. This group was further subdivided into those with an activity according to the 2010 German Classification of Occupations and an age of 20 to 64 years "employed" and persons over 64 years without an activity "retired". The dependent variable in a multiple Poisson model is an invasive spinal surgery, while insured characteristics were compared over a two-year period between those with and without surgery.

**Results:** Conservative therapies for spinal diseases indicate the severity of the disease, but can also influence the course of the disease. In order to differentiate between both effects, numerous control variables were used. These variables approximate the severity (prescription of pain medication/therapies, number of days of incapacity to work) and thus can rotate the effect of the therapy. This way, "protective factors" for surgery on the spinal column have been identified. In the model, inpatient rehabilitation reduces the risk of surgery, as do medical gymnastics, manual therapy and massage, each with the indication for the spinal column. In general, the effects of physiotherapy are greater in the subgroup of "employees" than in that of "pensioners". Age is a risk factor, while comorbidities such as osteoarthritis, rheumatoid arthritis or psychosomatic disorders simultaneously reduce the risk of an operation. Imaging, in particular magnetic resonance imaging (MRI), increases the risk of spinal surgery, as does treatment by various specialists, especially if neurosurgeons are involved.

**Discussion:** The calculations show that certain therapies can avoid or postpone surgery on the spine. An MRI diagnosis and the consultation of different (specialist) physicians is a combination which, with all other characteristics being the same, is more likely to lead to an operation. The further replacement of X-ray examinations by MRI examinations together with the specialization of the practitioners may have shifted the indication criteria. At the same time, medical budgets for remedies are unequally distributed among the regional associations of statutory health insurance physicians, which could limit the scope for conservative therapies.

#### SP 5

##### Minimally invasive transforaminal lumbar interbody fusion using augmented reality surgical navigation for percutaneous pedicle screw placement

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<sup>1</sup>Hôpitaux Universitaires de Strasbourg, Service de Chirurgie du Rachis, Strasbourg, France

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<sup>3</sup>Philips Healthcare, Department of Image Guided Therapy Systems, Best, Netherlands

**Study design:** Retrospective observational study.

**Objective:** The aim of this study was to evaluate the accuracy of percutaneous pedicle screw placement using augmented reality surgical navigation during minimally invasive transforaminal lumbar interbody fusion (TLIF).

**Summary of background data:** Augmented reality-based navigation is a new type of computer-assisted navigation where video cameras are used instead of infrared cameras to track the operated patients and surgical instruments. This technology has not so far been clinically evaluated for percutaneous pedicle screw placement.

**Methods:** The study assessed percutaneous pedicle screw placement in 20 consecutive patients who underwent single-level minimally invasive TLIF using augmented reality surgical navigation. Facet joint violation and depression by the inserted pedicle screws were evaluated. Secondary outcome such as radiation dose exposure, fluoroscopy time, and operative time were collected for three phases of surgery: preparation phase, pedicle screw placement, and decompression with cage placement.

**Results:** A clinical accuracy for screw placement within the pedicle (Gertzbein 0 or 1) of 94% was achieved. One screw violated the facet joint with a trans-articular pathway. The screw head did not depress the facet in 54%. The use of fluoroscopy during navigation correlated with patient body-mass index ( $r=0.68$ ,  $p<0.0001$ ). The pedicle screw placement time corresponded to  $36\pm 5\%$  of the total operative time of  $117\pm 11$  minutes. A statistically significant decrease of 10 minutes in operative time was observed between the first and last 10 procedures which corresponded to the pedicle screw placement time decrease ( $48\pm 9$  vs  $38\pm 7$  minutes,  $p=0.0142$ ). The learning curve model suggests an ultimate operative time decrease to 97 minutes.

**Conclusion:** Augmented reality surgical navigation can be clinically used to place percutaneous screws during minimally invasive TLIF. However, the lack of tracking of the location of the device requires intraoperative fluoroscopy to monitor screw insertion depth especially in obese patients.

Fig. 1

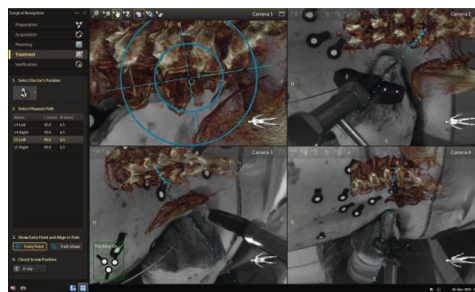
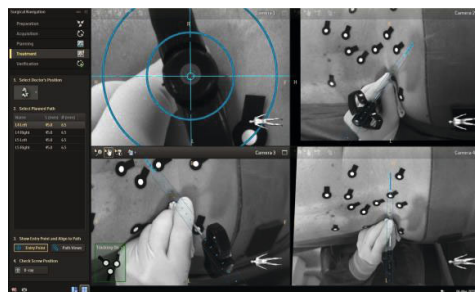


Fig. 2



## SP 6

**Histopathological samplings in kyphoplasties – in case of doubt, do it! – an analysis of 154 patients**\*B. Kunze<sup>1</sup>, O. Kessler<sup>1</sup>, L. Gössel<sup>1</sup>, S. Krebs<sup>1</sup>, C. Schätzl<sup>1</sup><sup>1</sup>Orthopädische Klinik Markgröningen, Neuroorthopädie, Markgröningen, Germany

**Introduction:** As a minimally invasive method, kyphoplasty is an established procedure for the treatment of vertebral compression fractures. Many of these fractures occur in advanced age without adequate trauma. Osteoporosis plays an important role in aetiology. Nevertheless, other causes, in particular pathological fractures must be excluded. The aim of the present study was the analysis of histopathological examinations in the context of kyphoplasties and (unexpected) positive findings.

**Methods:** The present retrospective data analysis includes 154 patients, who were treated with kyphoplasty in our clinic in the period 01/2018 to 04/2019. In 93 cases a biopsy was taken intraoperatively. The evaluation of the patient data, preoperative diagnostics as well as results of the histopathological examinations was done by reviewing the patient documentation system.

**Results:** In 154 patients (w: m = 122: 32) with an average age of 76 years (range 49–90 years), a total number of 215 vertebral bodies in the thoracic and lumbar spine were kyphoplasted. In 2.6% of patients a tumor was previously known. 49% of the patients had osteoporosis. Preoperatively, 96% of patients received magnetic resonance imaging (MRI), which showed pathological changes in 14 cases. An intraoperative biopsy was taken in 60% of the cases (n=93). In 7.5% (n = 7) of the samples taken, there was a positive histopathological result for the detection of malignant cells. Of these, 3 cases were lymphatic bone infiltration, 3 cases a metastasis of a newly diagnosed malignancy, and 1 case a metastasis of a previously known breast cancer. The correlation with preoperatively performed and conspicuous MRI is 100% true positive and 8% false positive MRI.

**Conclusion:** Osteoporosis is certainly the most common cause of vertebral compression fractures in old age. Nevertheless, the present work as well as preliminary work in the literature [1,2] showed that the rate of pathological fractures is not insignificant. In particular, in case of abnormalities in the preoperatively performed MRI but also anamnestic unclear genesis of the fracture, an intraoperative biopsy must be performed to detect an unknown pathological bone infiltration and to be able to initiate the necessary therapies.

[1] Uzunoglu I et al. Evaluation of incidentally detected pathology results of patients with vertebral fracture treated by vertebroplasty and kyphoplasty: a retrospective study. *World Neurosurg* (2019) Feb; 122: e639–e646

[2] Nowak S et al. Incidence of unexpected positive histology in kyphoplasty. *Eur Spine J* (2018) Apr; 27(4): 847–850

## SP 7

**Outcomes of bracing in juvenile idiopathic scoliosis – a retrospective single-center study among 77 patients**\*T. M. Fischer<sup>1</sup>, F. Galla<sup>1</sup>, U. Liljenqvist<sup>1</sup><sup>1</sup>St. Franziskus-Hospital Münster, Klinik für Orthopädie II – Wirbelsäulenchirurgie, Münster, Germany

**Objective:** The success of non-surgical treatment of scoliosis by bracing in juvenile scoliosis is discussed controversial with rates of surgical fusion between 5% and 80%. Our objective is to evaluate the rate of successful treated patients with JIS versus treatment failure (>5° progression after treatment or switch to surgical treatment).

**Methods:** Data was collected from patients treated in between 2007 and 2019 at St. Franziskus-Hospital Münster with JIS without any comorbidity. All patients were treated with any individual aligned brace and daily treatment time (from night-time-bracing to 23 hours a day).

**Results:** 77 of 172 patients with JIS matched the study criteria, 13 male and 64 female. 49 were still under treatment. 28 were recorded as finished treatment. The average age at diagnosis was  $7.4 \pm 1.6$  years (y) and at start of bracing  $8.5 \pm 1.4$  y. The daily

bracing time was  $16.9 \pm 5.8$  h/d whilst the period of treatment was  $6.9 \pm 1.7$  y. Age at the end of treatment was  $15.1 \pm 1.6$  LJ. Cobb-angle of the main-curve was  $27.0 \pm 6.4^\circ$ . 7 of 28 patients underwent surgery (25%), 8 patients (29%) stayed in conservative treatment but were recorded as therapy failure (curve-progression while treatment or after bracing >5°) and 13 pat. were treated successfully until skeletal maturity (46%). The group of successful treated pat. had a main Cobb-angle of  $26.2 \pm 6.1^\circ$  with a correction of  $77.6 \pm 22.07\%$  in the first brace. The permanent correction at the time of skeletal maturity was  $11.1 \pm 1.5^\circ$ . The difference in correction in the first brace and correction of the main-curve was statistically significant compared to the group of therapy failure ( $p < 0.05$ ). Patients who underwent surgery had a significant higher Cobb-angle at beginning of treatment and a longer daily bracing time compared to the successful treated pat. ( $p < 0.05$ ). The type of curve (thoracic vs. lumbar, single vs. double major curve) had no influence on the result.

**Conclusion:** A high initial correction in the first brace and a high compliance is a predictive factor for a successful bracing treatment in patients with JIS. Risk-factors for a surgical treatment are higher Cobb-angle, low correction in the brace and low compliance. Nevertheless the bracing treatment is able to create precious time for any patient to grow closer to skeletal maturity. We were able to prevent 75% our patients who finished the treatment from surgery.

## SP 8

**Comparison of cancellous bone density with the occurrence of insufficiency fractures in the cervical, thoracic, lumbar and sacral spine – a cadaver study**\*C. M. Kullen<sup>1</sup>, G. Schröder<sup>2</sup>, J. R. Andresen<sup>3</sup>, M. Schulze<sup>4</sup>, H. C. Schober<sup>2</sup>, R. Andresen<sup>1</sup><sup>1</sup>Westküstenklinikum Heide, Academic Teaching Hospital of the Universities of Kiel, Luebeck and Hamburg, Institute of Diagnostic and Interventional Radiology/Neuroradiology, Heide, Germany<sup>2</sup>Municipal Hospital Suedstadt Rostock, Academic Teaching Hospital of the University of Rostock, Department of Internal Medicine IV, Rostock, Germany<sup>3</sup>Sigmund Freud University, Medical School, Wien, Austria<sup>4</sup>University Medical School Rostock, Institute of Anatomy, Rostock, Germany

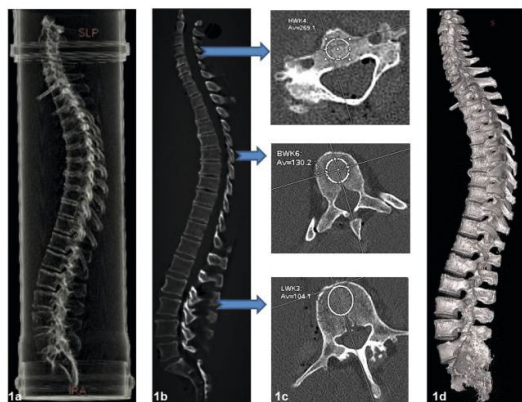
**Purpose:** Osteoporotic insufficiency fractures occur as a result of markedly reduced cancellous bone density above all in the thoracic, thoracolumbar and sacral regions – but not in the cervical spine. In order to understand this distribution, morphological and osteodensitometric investigations were conducted in the various spinal segments of donated cadavers by means of CT scans.

**Material & Methods:** To simulate a homogeneous, anatomically analogous body circumference, the complete spinal columns from 30 donated cadavers were mounted, as far as possible air-free, in a Plexiglas water phantom (sewer pipe made of hard polyvinyl chloride, PVC-U) with a diameter of 25cm and a length of 125cm (**Fig. 1a**). Then, a high-resolution spiral CT (GE Revolution EVO/64-line CT/ lateral scanogram, axial slice thickness < 1 mm, as well as axial and sagittal reformation with a slice thickness of 2mm) was performed. Two independent radiologists detected and graded vertebral body deformities in the sagittally reformed slices (**Fig. 1b**). At this point, spines with metastases, a diffuse idiopathic skeletal hyperostosis or pronounced scoliosis were excluded from the further investigation, so that 26 of 30 donor spines (average age  $81.2 \pm 8.1$  years) were evaluated further. For visualisation of the entire spinal anatomy, a 3D volume rendering was performed on an external workstation (GE AW-Server® Version 2.0. Measurement of the spines in GE Centricity RIS-i® Version 5.0), (**Fig. 1c-d**). Bone mineral content was determined by QCT (GE Revolution EVO / 64-line CT, Mindways Software 3D Volumetric QCT Spine). Cancellous bone mineral content was determined in a volume block at the level of vertebral bodies L1, L2 and L3, and the mean stated in mg/ml was used to estimate osteoporosis. An additional measurement of the CT-morphological cancellous bone density was performed in Hounsfield units (HU values) of the individual vertebral bodies from C3 to S1 (a total of 598 vertebral bodies), by means of a manually positioned ROI in the cancellous space (**Fig. 1d**).

**Results:** Osteoporosis was present in all of the spines. At a bone mineral content of below 60mg/ml, significantly increased sintering fractures were found in the thoracic and thoracolumbar region. Fractures were not found in the region of the cervical spine as a whole. The cancellous bone density was significantly ( $p < 0.001$ ) higher in the cervical (183.3 HU on average) than in the thoracic (94.2 HU on average), lumbar (64.1 HU on average) and sacral (59.4 HU on average) vertebral bodies of all spines investigated.

**Conclusion:** A loss of bone mineral content in the cancellous bone of vertebral bodies leads to an increased risk of fracture, which was also found in our spines. However, in the cervical region, a threshold value for the occurrence of sintering fractures is not fallen below, even in the case of manifest osteoporosis.

**Fig. 1**



## P 1 Radiation doses of sliding gantry CT-based as compared to mobile cone-beam CT-based navigated pedicle screw placement in a homogenous cohort

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**Background:** Today, multiple solutions for navigation-guided pedicle screw placement are available. For the present study, we compared the applied radiation doses of sliding gantry CT-based (SGCT) and mobile cone-beam CT-based (CBCT) pedicle screw placement for spinal instrumentation.

**Methods:** We retrospectively analyzed 183 and 54 patients who underwent SGCT-based using an automated radiation dose adjustment or standard CBCT-based pedicle screw placement for spinal instrumentation at our department between 06/2019 and 01/2020, respectively.

**Results:** Baseline characteristics including the number of screws per patient and the number of instrumented levels did not differ between the two groups. Although the accuracy of screw placement according to Gertzbein-Robbins classification did not differ between the two groups, more screws had to be revised intraoperatively in the CBCT group (SGCT: 39, 2.7% vs. CBCT: 23, 6.0%;  $p=0.0036$ ). Mean  $\pm$  standard deviation radiation doses [mGy\*cm] for the first (SGCT: 484.0 $\pm$ 201.1, CBCT: 687.4 $\pm$ 188.5;  $p<0.0001$ ), second (SGCT: 515.8 $\pm$ 216.3, CBCT: 658.3 $\pm$ 220.1;  $p<0.0001$ ), third (SGCT: 531.3 $\pm$ 237.5, CBCT: 641.6 $\pm$ 177.3;  $p=0.0140$ ), and the total of all scans (SGCT: 1216.9 $\pm$ 699.3, CBCT: 2000.3 $\pm$ 921.0;  $p<0.0001$ ) were significantly lower in the SGCT group. The same applies to radiation doses per level (SGCT: 461.9 $\pm$ 429.3, CBCT: 1004.1 $\pm$ 905.1;  $p<0.0001$ ) and radiation doses per screw (SGCT: 172.6 $\pm$ 110.1, CBCT: 349.6 $\pm$ 273.4;  $p<0.0001$ ).

**Conclusion:** The present results show that the applied radiation doses are significantly lower using a SGCT for navigated pedicle

screw placement in spinal instrumentation. A modern CT scanner on a sliding gantry leads to lower doses, especially through automated 3D radiation dose adjustment.

## P 2 Test-retest reliability in the determination of spinopelvic parameters after minimally invasive spondylodesis: Is my measurement of today the same as tomorrow?

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**Introduction:** The consideration of spinopelvic parameters is gaining importance for spine surgeons. Even relatively small angle changes due to surgery are reported as significant results. The measured values depend on the examiner. How, by whom or by how many examiners the values were determined is usually not described. It is not sufficiently known to what extent uniquely measured values are reliable and reproducible or whether the experience of the examiner makes a difference. This study examines the test-retest reliability of the measurement of spinopelvic parameters by two investigators with different expertise.

**Methods:** Segmental and lumbar lordosis angle as well as sagittal vertical axis (SVA) were measured on pre- and postoperative digital X-ray images of 43 prospectively included patients with monosegmental minimally invasive TLIF by 2 examiners (Rater1, Rater2) twice in an interval of 4 weeks. Rater1 was an experienced spine surgeon, Rater2 was a postgraduate student who was instructed in the measurement. To evaluate the test-retest agreement (intrarater reliability) the *Intraclass Correlation Coefficient (ICC)* was calculated for each parameter.

**Results:** ICCs were "excellent" ( $>0.9$ ) or "good" ( $>0.8$ ) for all parameters in both examiners (Table 1). In both examiners, the agreement was slightly lower for segmental lordosis angles than for lumbar lordosis, but the ICC was always  $>0.8$ . There was no difference in intrarater reliability between the examiners and thus no dependence on clinical experience. Although the absolute values showed a small, expectable, scattering between test and retest (0.5°–3.3°), there was no change in the statistical significance levels from preoperative to postoperative (Table 2).

**Discussion:** Multiple measurements of spinopelvic parameters by the same person showed good to excellent agreement. The clinical experience of the raters seems to be not relevant for the measurement of angles with respect to intrarater reliability. Therefore, a single measurement by a suitable person seems to be sufficient and repeated measurements are not necessarily required to improve accuracy. However, despite the high ICC values, it must be considered that the respective "true" value still cannot be determined beyond doubt. Whether statistically significant but small differences (sometimes  $<3^\circ$ ) can be regarded as relevant changes must always be critically questioned considering intrarater differences of up to  $3^\circ$ .

**Table 1:** Overview of the ICCs (95% confidence interval) of the two raters (intrarater reliability). An ICC $>0.9$  is considered "excellent" agreement, an ICC $>0.8$  is considered "good" agreement.

**Table 2:** Presentation of the pre- to postoperative lordosis angles and SVA of all 43 patients in the median (interquartile range). Both raters show constant statistical changes from pre- to postoperative in test and retest.

**Fig. 1**

		n	Rater 1 Spine Surgeon	Rater 2 Postgraduate Student	
Segmental lordosis angle	preoperative	43	0.911 (0.843–0.951)	0.896 (0.816–0.942)	ICC $>0.9$ : Excellent Reliability ICC $>0.8$ : Good Reliability
	postoperative	43	0.841 (0.726–0.910)	0.887 (0.800–0.937)	
	combined	86	0.880 (0.821–0.920)	0.896 (0.845–0.931)	
Lumbar lordosis angle	preoperative	43	0.946 (0.888–0.973)	0.958 (0.925–0.977)	
	postoperative	43	0.913 (0.824–0.956)	0.950 (0.899–0.974)	
	combined	86	0.931 (0.873–0.960)	0.954 (0.929–0.971)	
Sagittal vertical axis	preoperative	43	0.992 (0.986–0.996)	0.994 (0.980–0.997)	
	postoperative	38	0.935 (0.798–0.973)	0.992 (0.986–0.998)	
	combined	81	0.980 (0.960–0.989)	0.994 (0.981–0.998)	

Fig. 2

		Segmental lordosis angle				Lumbar lordosis angle				Sagittal vertical axis			
		preoperative	Δ	postoperative	p	preoperative	Δ	postoperative	p	preoperative	Δ	postoperative	p
Rater 1	Test	30.2°	+5.1	25.3°	0.001*	57.0°	+2.1	59.1°	0.171	24.9 mm	+1.2	26.1 mm	0.856
	Retest	(15.5–24.3)		(18.3–30.9)		(50.2–67.7)		(51.9–68.1)		(14.6–47.8)		(17.1–41.4)	
Rater 2	Test	19.2°	+4.6	23.8°	0.003*	56.0°	+1.3	57.3°	0.180	26.4 mm	-2.1	24.3 mm	0.695
	Retest	(16.1–25.7)		(19.0–28.4)		(49.1–64.3)		(50.5–63.1)		(14.2–50.4)		(9.8–40.7)	
Postgraduate Student	Test	17.2°	+3.9	21.1°	0.012*	59.3°	-2.2	57.1°	0.518	22.0 mm	+1.0	23.0 mm	0.577
	Retest	(13.2–22.7)		(18.2–26.3)		(50.2–66.0)		(50.9–66.7)		(13.1–46.0)		(6.3–39.0)	
		17.3°	+5.3	22.6°	0.003*	60.3°	+1.1	61.4°	0.085	21.4 mm	+3.9	25.3 mm	0.637
		(12.9–23.3)		(16.8–25.8)		(52.2–65.4)		(52.8–67.0)		(9.1–47.8)		(8.2–39.5)	

## P 3

### Using supine Magnetic resonance imaging (MRI) or Computed tomography (CT) versus functional radiographs to determine dynamic instability in patients with lumbar degenerative spondylolisthesis

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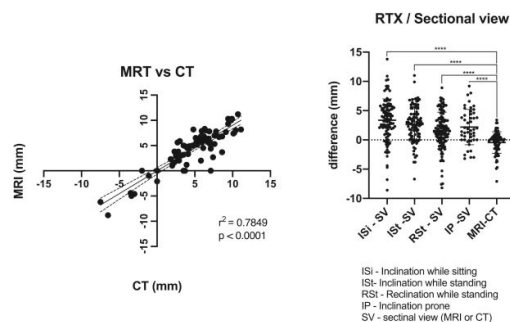
**Objective:** Spondylolisthesis is defined as anterior displacement of one vertebra relative to the adjacent vertebra. Spondylolisthesis is most common on level L4/L5 or, less commonly, L5/S1 or L3/L4. Symptoms arise through a combination of the degenerative changes, segmental instability and consecutive stenosis. In this study, we sought to identify the proportion of patients with dynamic instability using single functional radiographs compared to supine CT or MRI.

**Methods:** Data acquisition was conducted as a single-center retrospective analysis. Patients presenting with spondylolisthesis from June 1st, 2018, to May 30th, 2020 with functional radiographs and either CT or MRI were included in our analysis. The amount of translation, in millimeters, was calculated on supine MRI, CT and radiographs of inclination while sitting, -standing, reclination and prone using the Meyerding technique. The amount of translation was compared between CT and MRI (Fig 1) and each radiograph to either CT or MRI (Fig 2)

**Results:** One hundred and thirteen patients with spondylolisthesis on one hundred twenty-five vertebral levels were included in this study. The mean patient age was 73.52±12.59 years. 69 (60.5%) patients were female, 45 (39.5%) male. The most commonly affected level was L4-5 (62.4%). Levels L3-4 (16%) and L5-S1 (13.6%) were affected equally. The average translations measured on supine CT was 4.13±5.93mm and 4.417±3.492mm on MRI. The difference of inclination while sitting radiographs to slice imaging was 3.373±3.642mm, inclination while standing to slice imaging was 2.665±3.031mm, reclination while standing to slice imaging was 1.596±3.148mm and prone to slice imaging was 2.189±3.020mm. While no statistically significant difference was detected between CT and MRI, both were statically significant different to all radiographic modalities. The largest differences were detected between inclination while sitting and CT/MRI.

**Conclusions:** In this study, we analyzed the meaning of different functional radiograph modalities versus CT and MRI for detection of dynamic instability in lumbar spondylolisthesis. We showed that radiograph modality (inclination, reclination or prone) in comparison to CT or MRI is sufficient to detect lumbar instability. Therefore, putting patients through different positions during functional radiographic imaging causes avoidable radiation exposure, discomfort and costs to our health care system.

Fig. 1



## P 4

### Thermography – a suitable imaging procedure for postoperative control after lumbar dorsal spine surgery?

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**Introduction:** Surgical procedures on the lumbar spine are performed due to a variety of diseases; spinal surgeries in Germany have increased fivefold in the last 10 years, also as a result of new surgical procedures and access routes. Methods to detect potential early complications after spinal interventions are limited. The aim of this study was to investigate whether thermography is an appropriate imaging method for postoperative follow-up.

**Methods:** The immediate postoperative course after dorsal interventions on the lumbar spine of 50 patients was documented using an infrared thermography camera (FLIR ONE). The local findings were photographed daily as part of the wound controls at a distance of approximately 35 to 50 cm from the wound surface. Two investigators evaluated changes in surface temperature ( $\Delta T$ ) compared to the preoperative status in three ROIs using software (FLIR Tools).

**Results:** The data collected were compared with various common parameters used for process control. These included laboratory parameters (CRP, leukocytes, Hb), subjective pain (NRS), length of stay, as well as complications (post-operative bleeding, wound healing disorders). The measurements carried out showed regularly a postoperative increase in surface temperature; on average, the highest difference was on the third postoperative day ( $\Delta T = 8.1^\circ \text{C} \pm 2.0^\circ \text{C}$ ). One of the recorded wound healing disorders showed thermographic abnormalities before it manifested itself clinically. A significant correlation between the recorded temperature differences and laboratory abnormalities or complications could not be demonstrated in this study.

**Discussion:** The thermographic camera used in this study is an inexpensive, additional procedure for postoperative follow-up after lumbar dorsal spine surgery. However, due to various disturbances and limited technology, the camera we used has only a limited specificity and sensitivity. In principle, however, changes in the surface temperature can be risk factors predicting early postoperative complications. Therefore, thermography can be a suitable procedure for postoperative course and wound control.

Fig. 1

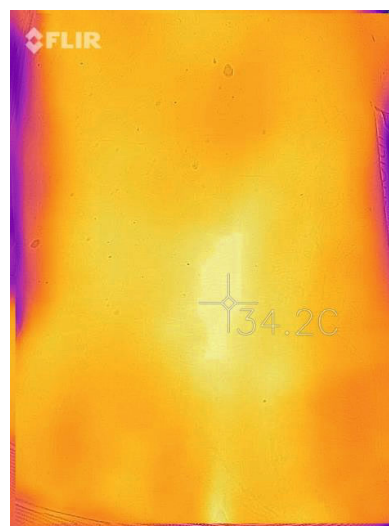


Fig. 2



## P 5

**Intraoperative computed tomography navigation for lateral approaches to the spine in a consecutive series of 13 patients**\*M. Pojskic<sup>1</sup>, B. Saß<sup>1</sup>, M. Bopp<sup>1</sup>, B. Völlger<sup>1</sup>, C. Nimsky<sup>1</sup>, B. Carl<sup>1,2</sup><sup>1</sup>Universitätsklinikum Marburg, Klinik für Neurochirurgie,

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**Objective.** Lateral approaches to the spine (lateral transposas retroperitoneal as well as lateral transthoracic) have gained increased popularity due to minimal invasive access to spine, less blood loss, decreased operative time and less postoperative pain. They can pose a challenge for neurosurgeons due to narrow safe working zone between nerves of the lumbar plexus, lungs and anatomical correlation to aorta when performing corpectomy. Objective of the study is to analyze the use of intraoperative computed tomography with navigation and implementation of augmented reality in facilitating the lateral approach to the spine.

**Methods.** We prospectively analyzed all patients who underwent surgery with lateral approach to the spine from September 2016 to January 2020. A total of 13 patients were investigated by intraoperative CT applying a 32-slice movable CT scanner, which was used for automatic navigation registration.

**Results.** 13 patients (6 female and 7 male), medium age 64.5 years, were operated using lateral approach to the thoracic (6 patients) and lumbar spine (7 patients) using intraoperative CT with navigation. Eleven patients were operated from the left side and two patients from the right side. Indications included myeloma of the lumbar spine (1 case), osteoclastoma of the 12th thoracic vertebra (1 patient), herniated disc (3 thoracic and 1 lumbar), instability following fracture of the thoracic or lumbar vertebra (2), neurinoma of the lumbar spine (1), tumor of the thoracic wall (1 patient), metastasis (2 patients) and spondylodiscitis (1 patient). Out of 12 patients, in 6 patients corpectomy was performed with implantation of the expandable cage and one patient underwent discectomy in XLIF-technique with cage implantation. Intraoperative CT verified desired extent of resection in all tumor cases as well as the accurate position of the implanted hardware. Automatic registration applying intraoperative CT resulted in high accuracy (target registration error:  $0.84 \pm 0.10$  mm). The effective radiation dose of the registration CT scans was  $5.76 \pm 3.32$  mSv. Augmented reality (AR) supported surgery by visualizing the tumor outline, pedicle screws, herniated discs and surrounding structures was used in 5 cases. One patient experienced perioperative complications. Three patients died in the early

postoperative course due to severe cardiorespiratory failure, due to sepsis unrelated to spine surgery and one patient due to tumor progress. Eight patients had improved and two had unchanged neurological status at the follow up.

**Conclusion.** Intraoperative computed tomography with navigation facilitates the application of the lateral approaches to the spine for variety of indication including fusion procedures, tumor resection and herniated disc surgery.

## P 6

**Long-term radiological and clinical results of radiolucent carbon fiber-reinforced pedicle screws in spine metastases**E. Archavlis<sup>1</sup>, \*L. Serrano<sup>1</sup>, S. R. Kantelhardt<sup>1</sup>, Y. S. Kang<sup>1</sup>, F. Ringel<sup>1</sup><sup>1</sup>Universitätsmedizin Mainz, Klinik für Neurochirurgie, Mainz, Germany

**Objective:** Metastatic spine lesions frequently require surgery in order to achieve decompression of the spinal cord and restoration of spinal stability. A variety of systems have been developed for dorsal stabilization. Recently, the use of carbon fiber-reinforced polyetheretherketone (CFRP) implants made early detection of a metastatic recurrence using sensitive imaging modalities like magnetic resonance imaging (MRI) possible in these patients without artifact interference. Furthermore, these artifact-reduced non absorbing implants can improve the delivery of the planned dose radiation distribution. In patients with prolonged life expectancy due to an improvement of both systemic and local therapy, treatment results can be impaired by a loosening at the implant-bone interface or mechanical failure. The aim of our study was to evaluate long-term radiological and clinical results of this relative new radiolucent system for pedicle screw stabilization in the thoracolumbar spine.

**Methods:** In a retrospective cohort study (2015-2018), 43 patients with metastatic lesions of the thoracic und lumbar spine were treated by posterior stabilization using CFRP pedicle screws. Postoperative imaging and clinical follow-up was possible in 40 patients. Data included all intraoperative remarks, incidence of complications, changes in neurological status, survival and imaging studies with CT and/or MRI.

**Results:** Good primary stability was achieved in all cases. The average follow-up period was 17 months, ranging from 6 to 36 months. A minimum follow-up of 1 year and 2 years was reported in 28 and 10 patients respectively. CT and/or MRI revealed no failure of the CFRP pedicle screws and rods. There were radiographic signs of implant loosening in 3 cases but no dislocation occurred. Follow-up MRI detected local metastatic recurrence at the sight of previous surgery in 10% of patients. Six patients suffered from wound healing problems, one patient experienced a proximal junctional failure, four patients had a serohematoma in the surgical region and three patients underwent revision surgery for misplaced pedicle screws.

**Conclusions:** From these data, it can be concluded that implantation of the new radiolucent system is safe and at least comparable with the commonly used titanium implants in terms of intra-, postoperative complications, stability at weight bearing and at functional recovery and provide sufficient long-term results for the requirements of selected tumor patients.

## P 7

**Surgical treatment of spinal osteoidosteoma – Retrospective analysis of 14 patients**\*U. Liljenqvist<sup>1</sup>, M. Schneider<sup>1</sup>, F. Galla<sup>1</sup><sup>1</sup>St. Franziskus-Hospital, Klinik für Wirbelsäulenchirurgie, Münster, Germany

Osteoidosteoma is a benign osteoblastic tumor of the adolescent/young adult which is located in 10% in the spine. Although relatively well known, the incidence is so low that in many cases the correct diagnosis is delayed. Aim of the study was to analyze the clinical course pre and post microsurgical nidus resection (n=12) or CT-guided thermoablation (n=2), patient

satisfaction and curve evolution in those patients with secondary scoliosis.

Retrospective analysis of 14 patients (3 female, 11 male) with surgical treatment at an average age of 25.6 yrs. (15 – 61 yrs). Preop. symptoms including radiculopathy, complications, recurrence rate, Cobb angle of scoliosis and patient satisfaction 12 months postop. were recorded.

Average delay of diagnosis was 20.1 months (3–48 m.). Typical symptoms were back pain at rest without any restrictions on exertion. 8 pts. reported of preop. radiculopathy, 5 pts. had a secondary scoliosis. All pts. showed the typical features on computed tomography (CT) with a nidus and a perifocal sclerosis. Preop. biopsies were not performed. In 12 cases the nidus was microscopically resected, in 2 cases a CT-guided thermoablation was possible due to the sufficient distance from critical neural structures. 8 pts. had a lumbar, 5 pts. a thoracic and one pt. a cervical localization. In 13 cases the diagnosis was confirmed histologically. 11 pts. were immediately painfree after intervention, 3 pts. reported a period of between 1 and 12 months until satisfactory pain relief. There were no perioperative complications. Preop. Cobbangle averaged 24.6° in 5 pts. and 12.6° after 2 years. Brace treatment was done in 3 pts. 9 pts. reported a 100% pain relief compared to preop., 4 pts. a 95% pain relief and one pt. 50% pain relief. 2 pts. complained of persistent dysaesthesia at follow-up. There were no recurrences.

The typical features of osteoidosteoma include a nidus and perifocal sclerosis on CT, clinically the pts. report on pain at rest responding to NSAID. Due to the critical proximity to neural structures microsurgical resection of the nidus is the standard of care. This technique is safe and leads to a 100% eradication rate. Postop. CT should document the complete resection of the nidus. Knowledge of the typical features of osteoidosteoma are paramount to avoid delay in diagnosis.

## P 8

### Dosimetric investigations of utilizing carbon fiber reinforced implants for postoperative spine stereotactic body radiation therapy

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**Introduction** Stereotactic body radiation therapy (SBRT) is increasingly used for treatment of spine metastases and might achieve superior local control and better pain response compared to conventional radiotherapy. In postoperative setting, target definition, patient setup and dosimetry are challenging due to the high-density material, which is typically used to build the stabilization hardware. Carbon fiber reinforced (CFR)-PEEK implants, using a composite of carbon and titanium (Icotec AG), could serve as an alternative in this situation. The aim of this study is to investigate the targeting accuracy and dosimetry in postoperative spine SBRT using the Cyberknife M6 (Accuray) in the presence of this dedicated stabilization hardware. Material and methods In order to assess the accuracy of the Cyberknife M6 with which the prescribed dose is delivered to a target (targeting accuracy) in the presence of stabilization hardware, the composite implant was inserted into a unique anthropomorphic torso phantom (CIRS). The Ball cube II (Accuray) was attached to the phantom and a standard End-to-End test was performed aligning the phantom in the spine region (spine tracking) and delivering the dose to the Ball cube II. To check the dosimetry, the results for dose distribution was measured when applying a clinically realistic treatment plan to a target located in the spinal column. For the measurement we used two planes through the spine with the aid of radiochromic films and finally compared that to the calculated dose distribution using the treatment planning system Precision (Accuray). Results The total targeting accuracy was found to be below 0.7 mm. The gamma passing rate when comparing the

measured dose with the calculated dose was found to be higher than 90% in all cases for a gamma criteria of 5% dose difference (global) and 1 mm distance to agreement when using a 20% dose threshold. Discussion and Conclusion Our phantom study showed that the application of postoperative spine SBRT in the presence of stabilization hardware consisting of a composite of carbon and titanium could be performed within clinically acceptable tolerances in term of targeting accuracy and dosimetry within a phantom.

## P 9

### Neurological outcome and respiratory insufficiency in intramedullary tumors of the upper cervical spine

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**Objective:** Patients suffering from intramedullary tumors of the upper cervical spine are at a high risk of postoperative neurological deterioration. As the levels above C4 are responsible for the diaphragm and volitional ventilatory control, patients may deteriorate, and experience permanent respiratory dysfunction with the need of long-term ventilation.

**Methods:** We conducted a retrospective review of all patients treated for intramedullary lesions including the upper cervical spinal cord above the C4 level in our neurosurgical department from January 2008 to December 2019. Patient's demographics, pre- and postoperative clinical status (including the modified McCormick grade) as well as operative technique, complications and follow-ups were assessed and analyzed.

**Results:** In total, 34 patients underwent a surgical treatment for intramedullary lesions including or above the C4 level from 2008 to 2019. Median age was 44 years, and 56% of the patients were male. The most common entity was ependymoma (22 patients, all WHO°II), 7 patients were treated for intramedullary glioma (WHO I-IV) and 5 patients for a hemangioblastoma. 22 patients (65%) presented with preoperative neurological deficits. Respiratory dysfunction was observed in only one patient requiring tracheotomy (2.9%). Postoperative neurological worsening was observed in 56% (motor function deterioration in 35% of the cases, sensory deficits in 50%), but the majority of patients recovered, and was independent at follow-up (median McCormick grade II, 76.7% of the cases with McCormick grade I and 2).

**Conclusions:** Intramedullary tumors of the upper cervical spine remain challenging neurosurgical entities. Despite their high-risk location, respiratory insufficiency remains a rather rare complication, while transient postoperative neurological deterioration is observed in more than half of the cases.

## P 10

### A change in protocol of wound care in spinal surgery and its impact on post-operative wound infections in neurosurgery

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**Background:** Surgical site infections (SSI) are an unfortunate post-operative complication responsible for morbidity. They account for 3% in spine surgery and can increase to 12% with instrumentation. Their treatment usually consists in a surgical revision associated with prolonged antibiotic therapy. This work focuses on wound closure technique, which has an essential influence on SSI. We recently introduced a closed wound dressing (*Dermabond* or *Dermabond* + *Prineo*) that is applied in the operating room. The aim of our study is to determine if a closed dressing protocol reduces SSI.

**Methods:** All patients diagnosed with SSI (based on inspection, clinics and MRI), during the initial stay or at readmission, are prospectively followed. Based on this data, we retrospectively included all primo-operated spine procedures from April 2016 to July 2017 in two different centers (Geneva, Switzerland, and Innsbruck, Austria). Data regarding patients, individual

infection risk factors, type of surgery and SSI were collected. They were separated in 2 general groups: *Closed-Protocol*, where we applied the dressing system *Dermabond* +/- *Prineo* (a self-adhering mesh with 2-octyl-cyanoacrylate skin glue, removed after 14 days; and *Conventional-Protocol*, which included dermal, intradermal sutures or staples. Surgical closure of fascia and subcutaneous layer was identical in both groups. For preliminary analysis, we compared the infection rate of each closure type versus all others.

**Results:** 672 patients were included in our study: 157 received staples, 122 skin sutures, 101 intracutaneous closure, 78 *Dermabond*, 217 *Dermabond*+*Prineo*. The infection rate was 2.4 % (n= 16). The highest infection rate was observed with skin sutures (4.9%) and the lowest was with *Dermabond* (1.3%) and *Dermabond* + *Prineo* (1.4%) compared to an overall infection rate of 2.4%. However, only skin sutures showed a statistically significant difference versus all other closures (4.9% versus 1.8%,  $p = 0.05$ ). Despite having lower rates of infection, *Dermabond* (1.3% versus 2.5 %,  $p = 0.43$ ) or *Dermabond*+*Prineo* (1.4% versus 2.9%,  $p = 0.24$ ) did not have significantly lower infection rates.

**Discussion:** Surgical site infections are significantly higher with skin sutures. *Dermabond* or *Dermabond-Prineo* had the lowest infection rates, but a larger cohort is necessary to demonstrate a significant superiority versus all other closure types. Further investigation via a multicentric controlled randomized trial is planned.

## P 11

### A comparison, using Micro-CT, of the architecture of cancellous bone from the cervical, thoracic and lumbar spine using 480 vertebral bodies from 20 body donors

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**Introduction:** Structure of bone alters with increasing age. Material and structural properties are both important for bone strength. Despite having an ageing society, there is a paucity of data from elderly subjects relating to these parameters. We examined bone cylinders from the centres of vertebral bodies C1 to L5 from elderly subjects with respect to their bone volume (BV/TV), trabecular thickness (Tb. Th.), separation (Tb.Sp.), trabecular orientation (SMI) and degree of anisotropy (DA).

**Methods:** 480 core samples (Jamshidi needle 8G) were stabilised in wet gauze and prepared in 1.5ml Eppendorf reaction vessels. The examination was made using a  $\mu$ -CT (SKYSCAN 1172, RJL Micro & Analytic Company, Germany). A flat field correction, and generation of phantoms (reference), with density of 0.25 g/cm<sup>3</sup> and 0.75 g/cm<sup>3</sup> was carried out. This study received the approval of the ethics committee.

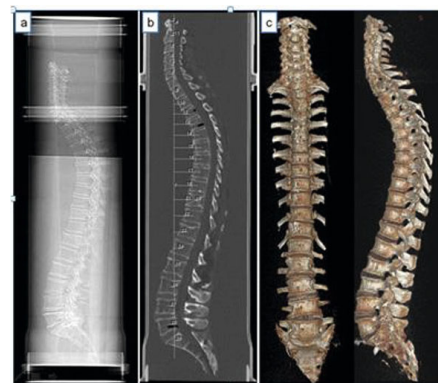
Data was analysed using SPSS, Version 24.0 (SPSS Inc., Chicago, USA). Comparisons between the groups utilized the Kruskal-Wallis test, followed by a pairwise comparison. The Shapiro-Wilk-test was used to test for Normal distribution.

**Results:** Regarding BV/TV ( $p < 0.001$ ), Tb.Th. ( $p = 0.001$ ), Tb.Sp. ( $p < 0.001$ ), SMI ( $p < 0.001$ ) there were statistically significant differences between the segments of the vertebral column. A pairwise comparison yielded the following: BV/TV, HWS vs. BWS,  $p = 0.010$ , HWS vs. LWS,  $p < 0.001$ , BWS vs. LWS,  $p > 0.05$ ; Tb.Th., HWS vs. BWS,  $p = 0.045$ , HWS vs. LWS,  $p < 0.001$ , BWS vs. LWS,  $p > 0.05$ ; Tb.Sp., HWS vs. BWS,  $p = 0.004$ , HWS vs. LWS,

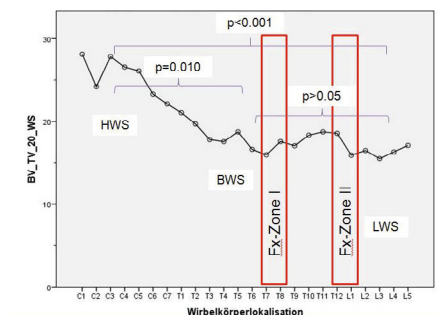
$p = 0.001$ , BWS vs. LWS,  $p > 0.05$ ; SMI, HWS vs. BWS,  $p = 0.006$ , HWS vs. LWS,  $p < 0.001$ , BWS vs. LWS,  $p > 0.05$ .

**Conclusion:** Cervical vertebrae have a unique microarchitecture which gives them their strength. Specifically, this entails a higher BV/TV, Tb.Th. and lower Tb.Sp. In addition, the SMI demonstrates more plates than rods.

**Fig. 1**



**Fig. 2**



## P 12

### Interleukin-6 as inflammatory marker of surgical site infection following spinal surgery

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**Introduction:** In order to elucidate whether serum inflammatory markers identify patients with local surgical site infection (SSI) as underlying disease for recurrent or new symptomatology following spine surgery, we evaluated the diagnostic potential of interleukin-6 (IL-6) as a marker of SSI in patients undergoing spinal re-operation. The diagnostic significance of IL-6 was compared to the standard serum inflammatory markers C-reactive Protein (CRP) and white blood cell count (WBC).

**Material/Methods:** We reviewed the medical records of all patients undergoing an elective dorsal decompressive surgery at our neurosurgical university center between November 2011 and April 2016 due to degenerative disorders of the cervical, thoracic or lumbar spine. Those patients who were readmitted during follow-up and needed re-operation due to recurrent symptomatology or SSI entered the study. Baseline patients' characteristics as well as the above mentioned inflammatory markers were collected and arithmetical means with standard deviation, area under the curve (AUC), thresholds, sensitivity, specificity, positive (+) likelihood ratio (LR) and negative (-) LR with corresponding 95% confidence interval (95%CI) were calculated and correlated with presence or absence of SSI. Reference range for CRP was  $\leq 0.5$  mg/dl and it was  $\leq 6.3$  pg/ml for IL-6.

**Results:** Out of altogether 633 patients with an elective dorsal decompressive spine surgery during our 5-years observational period, 98 patients were readmitted for revision surgery due to recurrent symptomatology or SSI (re-operation rate: ca. 15%). 9 patients suffered

from a SSI, whereas the remaining 89 patients had a recurrent/adjacent-segment degenerative disorder without any suspicion of SSI. The most significant parameter for diagnosing a SSI was serum IL-6 (cutoff-value > 15.3 pg/ml, AUC = 0.954, SE = 85.7%, SP = 97.3%), followed by CRP (cutoff-value = 0.8 mg/dl, AUC = 0.916, SE = 88.9%, SP = 84.5%).  
**Discussion:** In case of recurrent symptomatology and suspected SSI, raised serum IL-6 levels are significantly associated with SSI. Hence, serum concentrations of IL-6 should be obtained in patients with recurrent symptoms; increased IL-6 levels higher than 15.3 pg/ml should direct the surgeon's attention to SSI.

### P 13

#### Evaluation of image quality and assessability of a new flat-panel 3D c-arm compared to mobile and fixed computed tomography in posterior fixation

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**Introduction:** In operative treatment of spine injuries, precise placement of implants is crucial, especially in regard to neurovascular structures. Intraoperative 3D imaging has proven itself as a reliable method to evaluate implant positioning. So far, these devices were based on image intensifiers (II). This may lead to impairments of image quality, especially due to artifacts that are generated by metal implants. To improve image quality, intraoperative CT scanners were developed, as well as a new generation of detectors for 3D c-arms (flat-panel, FP). In this study, image quality of a novel FP-based 3D c-arm compared to intraoperative and fixed computed tomography (CT).

**Material and methods:** Two whole body specimen with different bone quality were used for this study. Posterior fixation was performed on levels C5-Th2, Th11-L2 and L5-Iliac bone. 3D scans were performed (FP device Siemens Cios Spin, II device Siemens Arcadis Orbic, both Siemens, Erlangen, Germany) as well as CT scans (mobile intraoperative CT Airo, Brainlab, Munich, Germany, fixed CT Aquilion 16, Toshiba, Tokio, Japan). Assessment of the data was done by two blinded examiners with a semi-objective assessability score (valued 0-2 with 2 being best) as well as measurements of the screw course in the pedicle and perforation of the anterior vertebra.

**Results:** A statistically significant difference in the assessability score comparing all modalities could be observed  $\chi^2(2) = 82.660$ ,  $p < 0.001$ . II-based scans were rated as severely comprised with a value of  $0.11 \pm 0.28$ . Fixed CT was rated impaired as well with a score of  $0.56 \pm 0.56$ . Intraoperative CT was rated good with a score of  $0.91 \pm 0.41$ , while FP-based values were best with  $1.46 \pm 0.41$ . Regarding measurements of screw course in the pedicle as well as anterior wall penetration did not show statistical significant differences.

**Discussion:** Analysis of results show a remarkable improvement of image quality with the novel device. Regarding the semi-objective assessability score, even a statistically significant difference could be observed. New-generation FP-based 3D c-arms offer an image quality comparable to (fixed and intraoperative) CT devices as well as having advantages regarding usability, cost and regulatory issues.

### P 14

#### Augmented Reality – The Future of Spine Surgery?

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**Background:** Augmented reality (AR) is an emerging technology which superimposes digital images onto the real-world environment. With AR, relevant surgical anatomy can be projected onto an intraoperative CT scan used for navigation purposes, and imported directly into the user's line of sight in the microscope. In

minimally invasive spine surgery (MISS), the narrow working corridor makes visualization of relevant surgical anatomy challenging. AR may be useful to identify relevant anatomy early on which can improve surgical planning and targeting.

**Objective:** We undertook this preliminary study to evaluate the utility of AR in minimally invasive spine surgery. Specifically, we sought to investigate the use of preoperative MRI scans with selected anatomy combined with intraoperative CT images that would be projected into the microscope at the time of surgery. We performed this study to determine the impact on patient outcome, incorporation into operative work flow, operative time, and effective radiation dose.

**Methods:** The prospective case study was conducted on data collected from patients who underwent elective spinal surgery between August 2019 and October 2019 for intradural and extradural spinal lesions (e.g. intradural tumors, extradural tumors, cysts, disc herniations, spondylolisthesis). Prior to surgery, we reviewed the patient's preoperative MRI or CT scans and used the "smart brush" function to identify and "paint" anatomy relevant to the procedure being performed. For instance, in a minimally invasive transforaminal inter body fusion (MIS-TLIF), the pedicles, the pars, lamina and disc space were all highlighted in different colors. This preoperative image data was then fused to the intraoperative AIRO CT (BrainLAB, Munich, Germany). Fused datasets were visualized in the spinal navigation application on the navigation monitor and also in the microscope. All procedures were recorded for evaluation and for time measurements.

**Results:** In our cohort of 13 patients, the average AR set up time was 0.26 hours (0.02 – 0.52 hours). The average total effective dose was 12.8 mSv (5.1 – 21.45 mSv) per scan for each patient.

**Conclusion:** Our analysis suggests that while the use of AR increases set-up time by approximately 26 minutes, it can increase the safety, accuracy, and efficiency of an MISS case. Specifically, AR allows for more precise targeting of pathology (tumor, disc herniation, etc.) relative to bony landmarks on CT. In addition, nearby structures can also be mapped on preoperative imaging to provide confirmation of relevant anatomy. Our preliminary experience suggests that AR can be a useful technology to improve the workflow and should be investigated with further studies.

### P 15

#### The Role of Intraoperative Image Guidance System (3D C-arm vs. O-arm) in the Spinal Surgery: Results of a Single-Center Study

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**Objective:** Spinal dorsal instrumentation is an established treatment option for a range of spinal disorders, including degenerative diseases, trauma, infection, and neoplasia. In combination with navigation, intraoperative fluoroscopy reduces the risk of incorrectly placing screws. This study aimed to evaluate the efficacy and validity of fluoroscopy (intraoperative navigation with 3D rotation of C-arm vs. O-arm) for placing screws and verifying the placement during spinal surgery as compared with postoperative control CT scans.

**Methods:** In this retrospective single-center study, 240 patients were included between July 2017 and April 2020. Intraoperative images were acquired using a Siemens-Arcadis Orbic 3D C-arm with a dedicated navigation system (Vector Vision, Brainlab) or using O-arm (Medtronic) with a dedicated navigation system (S7 StealthStation). Postoperative surgical complications, including neurological deficits, wound healing disorder, and need for revision, among others, were assessed. The final position of the screws was verified by a postoperative CT scan. Finally, we compared mismatches between intraoperative and postoperative CT imaging results using Rampersaud-score (A-D)

**Results:** A total of 1614 screws were included in the evaluation: 94 patients in the C-arm group (cAG) and 146 in the O-arm group (oAG). After implantations, a second scan was performed intraoperatively. In cAG, 3% (n=20) of the screws had to be replaced directly due to inadequate positioning, and 3.5 % of

screws in oAG (n=35) showed median or lateral projections. An A-score was achieved for 85.7% in the cAG and 87.4% in the oAG. A B-score was found in 11.5% in the cAG and 11.9% in the oAG. In the cAG, a C-score was achieved for 2.5% and in oAG for 0.7%. For 0.3% of the screws a D-score was found in cAG and for none in oAG.

**Conclusion:** The data of our study shows that placement of screws using intraoperative imaging in combination with navigation tool is effective. Furthermore, navigation coupled with the O-arm had significant advantages in accuracy over navigation with 3D C-arm fluoroscopy.

## P 16

### Microcarrier-based cultivation of human intervertebral disc cells in an automated and regulated stirred bioreactor

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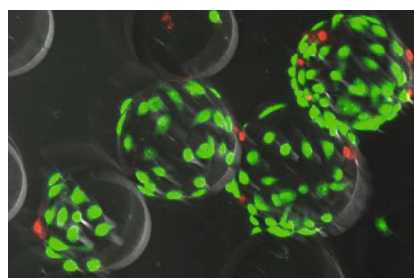
**Objective:** For a clinical application in cell-based therapies and tissue engineering approaches using scaffolds or hydrogel injections to regenerate intervertebral discs (IVD), high amounts of cells must be generated under controlled and reproducible conditions. Microcarrier-based cultures could show their abilities to promote extensive cell expansion, especially in stirred cultivation systems under desired conditions.

**Material/Methods:** We isolated IVD cells (n=3) and expanded them up to passage 2. Then, we cultivated them on Cytodex-3 microcarriers in a stirred, automated and regulated DASGIP Mini Spinner bioreactor for 10 days in 50 mL medium. Empty microcarriers were supplemented and the volume was increased to 100 mL. The cells were further cultivated for 7 days in the DASGIP bioreactor. The applied process parameters were: 36 °C, 50 rpm agitation, pH 7.4 and 25 % dissolved oxygen. The process was monitored and regulated over the whole time by the bioreactor system. The medium was automatically changed every second day. As a control a standard monolayer cultivation was performed. Analytical samples were taken every second day during the bioreactor cultivation. The cell growth was evaluated by a metabolic activity assay (MTT) and by measuring glucose and lactate concentrations in the medium. At the final day of cultivation the cell vitality on microcarriers was visualized by live/dead staining. Cells were harvested by dissolving the microcarriers enzymatically and flow cytometric analysis of the cells was performed.

**Results:** MTT assays and measurement of glucose/lactate concentrations in the medium revealed an increasing number of cells in accordance with a glucose consumption and lactate production over time. The cell proliferation rates were slightly lower compared to monolayer cultures. Due to the monitored and regulated process parameters high cell numbers were reached at the final day of cultivation. The supplemented empty microcarriers, after 10 days, were colonized during the stirred cultivation process. After 2 weeks only few dead cells were found using acridin orange (green-alive)/propidium iodid (red-dead) staining (fig. 1). For flow cytometry, bioreactor expanded cells in comparison with monolayer cultivated cells showed no differences for the tested surface marker CD105, CD73, CD90, CD44, as well as no expression for CD14, CD34, and CD45.

**Discussion:** Taken together, we established an automated and regulated bioreactor cultivation procedure for IVD cells, which resulted in high cell numbers. The cells kept their typical surface marker profile. Cells could easily be harvested without the negative, harmful effects of trypsin by dissolving the microcarriers enzymatically. Considering a clinical admission of these cells as an 'Advanced Therapy Medicinal Product' (ATMP), the whole cultivation is monitored and recorded as a proof of functional process.

Fig. 1



## P 17

### Ergometric improvement of working place in the operating theatre to improve capability and physical health for OR staff

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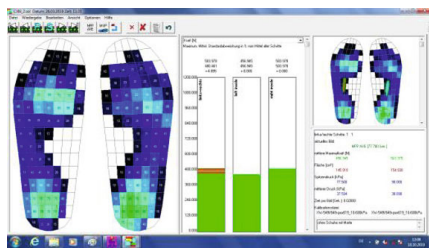
**Introduction:** Working place of spine surgeons in the operating room (OR) requires permanent standing occupation in a monotone constrained posture. The static load is often aggravated by burden of an X-ray lead gown. Working times in excess of 10 hours are not rare due to economic reasons. The ergonomic arrangement of the working place in the OR is therefore an important measure to improve and preserve capability and physical health for surgeons and assisting staff.

**Methods:** In a prospective, oligocentre observational study with N=30 participants evaluation was carried out, whether the use of a polyurethane foot mattress of 2 cm thickness would influence subjective capability and physical health. According to a standardized questionnaire, subjective parameters before, during and after the working process in the operating room were recorded. N=4 questionnaires with versus without use of a foot mattress of each study participant were analysed. Further, N=10 participants were included for anatomical and ergonomical evaluation in a gait lab at our institution. In addition, electronical plantar footprint measurement and optical -pedobarography and gravity loading for each foot were revealed by using a sensoric sole, which analysed 5-minute-standing and movements in a simulated working situation, comparable to reality in the OR.

**Results:** 83% of N=30, so in 120 consecutive questionnaires, participants reported a positive effect as well as an improvement of capability by using a polyurethane foot mattress independent of the duration of use. A reduction of weariness, leg pain and lower back pain was reported for use of a foot mattress in excess of 4 hours (p<0.05). Pedobarography for a 5-minute-simulation of standing and working in the OR revealed an improvement of centre of pressure in the analysed feed. The mean pressure was with a significant improvement of P<0.5.

**Conclusion:** Ergonomic arrangement of the individual working place is an established matter of course according to the guidelines of workers compensation board. Working place of spine surgeons and operating staff leads to a wearing and constrained posture. The flexible standing position on a polyurethane foot mattress leads to a significant performance enhancement and improvement of physical health of the spine surgeon and the operation staff.

Fig. 1



## P 18

### Conversion to digital documentation with implementation of SOP checklists for various spinal disorders and admission constellations for the admission procedure in the spine center

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**Introduction:** The improvement in the quality of care is not only achieved by defining processes as SOPs, but by reviewing and adapting them (change management). As part of the introduction of digital documentation of the admission procedure and implementation of the SOPs of various spinal disorders and admission constellations in the spine center, an analysis of the documentation of the admission procedure and the degree of implementation of the corresponding SOP was carried out through participatory supervision and subsequent adjustment of the process and repetition of the analysis as a PDCA cycle.

**Methods:** After the introduction of the digital documentation of the patient's medical history and examination with implementation of checklists in the sense of an SOP excel for the admission procedure for various spinal disorders and admission constellations in the spine center, the implementation was analyzed using a retrospective sample of 85 consecutive elective- and emergency-admission procedures of 8 residents. For the evaluation, the admission procedures were categorized into ten essential items. (Allocation, type of treatment, diagnosis, anamnesis, standard queries, safety checklist, examination findings, radiological / technical findings, specific SOP checklist, verification). The items were categorized: correct (2 points); may be improved (1 point); incorrect or missing (0 points). The results were then discussed in a motivating fashion with each resident. In the conversation we tried to identify the reasons for incorrect items. As a result of this procedure, the admission procedure for elective and emergency recordings was refined and adapted. The analysis was repeated after 3 months.

**Results:** For the item analysis, the sample averaged 77.5% of the maximum score. Uncertainties in the admission of emergency patients were uncovered. The electronic admission procedure for emergency patients has therefore been adjusted. In addition, not all items were reasonably accessible or necessary in all cases. Therefore, the maximum score could not be achieved or measured. The documentation for these cases was then adjusted. The residents were asked to mind all items in the upcoming admissions and to point out new inconsistencies or suggest improved procedures. When the analysis was repeated after 3 months for all 8 residents, an average score of 95% was found.

**Conclusion:** The introduction of a new way of documentation with implementation of SOPs using checklists generally requires monitoring and review. During this process helping and hindering factors for implementation can be identified. Our analysis identified a significant proportion of organizational obstacles. The deficits and ambiguities of the process were identified and eliminated through motivational involvement of the residents. Personal obstacles could be reduced during the time of observation. The participatory approach showed a high level of acceptance and motivation of the residents.

## P 19

### End plate changes in infectious spondylodiscitis

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**Introduction:** In most cases of spondylodiscitis, the ventral parts of the spine are affected and, depending on the extent of the disease, the cover and base plates of the affected vertebral bodies are destroyed.

The aim of the work was to map vertebral end plates in computertomographic examinations of patients with spondylodiscitis and to measure the extent of destruction.

**Material:** Retrospectively 50 vertebral end plates from patients with spondylodiscitis were randomly included, classified according to Eysel and Peters, and the base and cover plates were finally analyzed.

Patients who had postoperative spondylodiscitis or who could be assigned to stages 1 and 4 according to Eysel and Peters were excluded. The vertebral end plates were three-dimensionally reconstructed. The end plates were then divided into 8 areas and additively into central and marginal locations. In addition to the localization of the destruction, the area and depth were determined.

**Results:** With regard to the extent of destruction, n = 31 (62%) were stage 2 and n = 19 (38%) stage 3. according to the classification of Eysel and Peters. The area of the destruction was a minimum of 13mm<sup>2</sup> and a maximum of 1133mm<sup>2</sup>. The general average was 412mm<sup>2</sup>.

The mean value for the group stage 2 could be calculated with 300mm<sup>2</sup> and for the group stage 3 with 594mm<sup>2</sup>. The comparison between the groups shows a statistically significant result of p = 0.000030. The depth of the destruction is 3.2mm at the minimum and 14.3mm at the maximum with an average of 8.7mm (group stage 2: 8.10mm, group 3: 9.7mm). The comparison between the groups shows a clear trend, but the difference is not significant (p = 0.057370).

When examining the central and marginal areas, the comparison of the frequency for the central areas results in an average of 5.66 affected areas and an average of 4.54 in the marginal areas. The t-test showed a significant difference in the mean values for marginal and central areas (marginal p = 3.3E-19 and central p = 2.7E-18).

**Discussion:** In summary, there was a clear correlation between the conventional radiological classification according to Eysel and Peters and the extent of destruction of the base and cover plate. The depth of the destruction is independent of the stages.

Overall, the central areas of the vertebral end plates are affected significantly more often than the peripheral areas, which is important for the selection of suitable intervertebral support.

## P20

### Influence of the intraoperative CT use on surgery time

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**Aims:** To evaluate the influence of the use of the intraoperative CT on the surgery time.

**Methods:** Retrospective analysis of 171 surgeries performed in our department in two time periods (2013, 2017). Inclusion criteria: dorsally instrumented surgery on degenerative spine disease.

**Exclusion:** presence of tumor, infection, trauma, dorsoventral procedures. Procedures were graded according to the number of screws and cages placed, use of cement, use of ileum screws occurrence of dural tear, whether the surgery was minimally invasive, the surgeon performing the procedure or whether the surgery was a revision after previous surgery on the same segment. Linear regression models with stepwise factor selection based on Akaike information criteria were created for procedures with one cage and more than one cage with incisure to suture time as response variable.

**Results:** For procedures with 1 cage placed, the incisure-to-suture time was prolonged by the CT scan (p<0.001). Other significant

factors included the number of screws used ( $p=0.01$ ), presence of a dural tear ( $p=0.005$ ), number of segments decompressed ( $p=0.02$ ) and the use of ileum screws ( $p<0.001$ ). Two surgeons performed the procedures faster ( $p=0.02$  and  $0.03$ ).

For procedures with 2 or more cages placed, the number of screws used ( $p<0.001$ ) and the individual surgeons performance in three surgeons ( $p$  values 0.02, 0.04 and 0.04) were identified as significant factors with the above described statistical method.

**Discussion:** Although intraoperative CT based navigation arguably adds time to the surgery, this effect is only pronounced in short fusions. Further analysis including various other response variable (blood loss, infection rate, length of stay etc.) is planned. Currently, given the known benefits of CT based navigation, the use of CT is justified especially in multi-segment procedures.

## P 21

### Posterior transdural resection of giant calcified thoracic disc herniation: a case series of 12 patients

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**Objective:** Calcified thoracic disc herniations present a challenging entity for spine surgeons. Due to the close proximity to the spinal cord and relative narrowing of the spinal canal, the optimal approach is still matter of debate. While the transthoracic approach is usually preferred, we applied a new technique described in 2012: the transdural posterior approach. Our aim was to evaluate its benefits in patients with giant thoracic disc herniations.

**Methods:** We performed a retrospective review of all patients treated in our neurosurgical department from July 2012 to March 2020 for giant thoracic disc herniations through a posterior transdural approach. Demographics, pre- and postoperative clinical status, and operative technique and complications were extracted and analyzed.

**Results:** In total, we identified 12 patients who underwent a posterior transdural resection of giant calcified thoracic hard discs between 2012 and 2020. All patients underwent a posterior decompression (laminectomy, hemilaminectomy or laminoplasty). The median duration of surgery was 152 minutes, median length of hospital stay 10 days. Transient postoperative neurological deterioration occurred in 4 patients (33.3%), with complete recovery until time of discharge. No patient underwent a surgical revision.

**Conclusion:** The transdural resection of giant calcified thoracic hard discs through a posterior approach provides an excellent decompression with sufficient visualization of the spinal cord and a satisfying postoperative outcome.

## P 22

### External Validation of the Timed-Up-and-Go (TUG) Test as Measure of Objective Functional Impairment in Patients with Lumbar Degenerative Disc Disease

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**Background:** The Timed-Up-and-Go (TUG) test is the most commonly applied objective measure of functional impairment in patients with lumbar degenerative disc disease (DDD). Its reliability and relationship with commonly used patient-reported outcome measures (PROMs) was demonstrated in a seminal article five years ago. So far, no external validation was conducted.

**Material/Method:** Consecutive adult patients, scheduled for elective lumbar spine surgery, were enrolled into a prospective

observational study. We collected basic demographic and disease-specific information. Disease severity was estimated by filing out a set of PROM questionnaires (Visual Analog Scales (VAS) for back and leg pain, Core Outcome Measures Index (COMI) Back, Zurich Claudication Questionnaire (ZCQ)) and the TUG test was conducted. We calculated Pearson correlation coefficients (PCCs) to describe the relationship between logarithmic TUG test raw values (in seconds (s)) and PROMs.

**Results:** A total of 70 patients (mean age  $55.9 \pm 15.4$  years; 38.6% female; 27.1% with previous spine surgery; 28.6% with lower extremity motor deficits) with lumbar disc herniation (50%), lumbar spinal stenosis (34.3%) or instability requiring spinal fusion (15.7%) were included. Mean TUG test time was  $10.8 \pm 4.4$ s, age- and sex-adjusted OFI T-score was  $134.2 \pm 36.9$ . Twelve (17.1%) patients had mild OFI, 14 (20%) moderate OFI and nine (12.9%) severe OFI, while 35 (50%) had TUG test results within the normal population range (no OFI). PCCs between TUG test time and VAS back pain were  $r=0.37$  ( $p=0.002$ ), VAS leg pain  $r=0.37$  ( $p=0.002$ ), COMI Back  $r=0.50$  ( $p<0.001$ ), ZCQ symptom severity  $r=0.41$  ( $p<0.001$ ), ZCQ physical function  $r=0.36$  ( $p=0.002$ ).

**Discussion:** When compared with the original report, this external validation demonstrated similar OFI rates and correlation coefficients between logarithmic TUG test results and subjective PROMs. We confirm the TUG test to be a quick, easy-to-use objective test, which provides the physician with a robust estimate of pain and disability in the setting of lumbar DDD.

## P 23

### Influence of postoperative drainage volume on the in-hospital course

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**Introduction:** Suction drainage is mainly used to reduce postoperative liquid collection for reducing complications and improving recovery. To evaluate this thesis we compared the drainage volume after monosegmental TLIF (transforaminal lumbar interbody fusion) and PLIF (posterior lumbar interbody fusion) with clinical postoperative parameters in this prospective study.

**Material:** Inclusion criteria were monosegmental PLIF and TLIF. Patients with spinal tumor disease and accidental excavation of the drainage tube before readmission to the ward were excluded. In total 28 patients, of whom 19 underwent TLIF and 9 PLIF, and their clinical course were prospectively documented. Therefor postoperative drainage volume was measured three times a day for three consecutive days and pain was evaluated through NRS (Numerical Rating Scale) at the same time. Furthermore we recorded the duration of surgery, the duration of the hospital stay and intraoperative blood loss. In addition we compared the two techniques regarding the parameters mentioned above.

**Results:** At first we compared the datasets for PLIF and TLIF via Mann-Whitney-U-Test. The duration of surgery was significantly lower in TLIF than in PLIF ( $U=43$ ,  $Z=-2.092$ ,  $p=0.037$ ).

There was no significant correlation between the postoperative scale of pain and the total drainage volume, temporary drainage volume, duration of surgery or the intraoperative blood loss.

Also, the duration of surgery, total drainage volume and intraoperative blood loss did not correlate significantly with each other. However we were able to identify a correlation between the drainage volume at postoperative readmission to the ward (initial drainage volume) and the total drainage volume (Pearson correlation coefficient 0.619, Sig. (2-tailed) 0.018,  $N=14$ ). Furthermore the initial drainage volume correlates with the duration of the in-hospital stay (Pearson correlation coefficient 0.751, Sig. (2-tailed) 0.0003,  $N=18$ ).

**Discussion:** In the short term postoperative observation the pain level did not correlate with either the drainage volume at any point in time, intraoperative blood loss or duration of surgery. The initial drainage volume when readmitted to the ward however did correlate significantly with total drainage volume and the duration of the in-hospital stay.

We conclude, that sufficient intraoperative surgical hemostasis should be highly emphasized to improve the postoperative course of the in-hospital stay and its duration. Since in-hospital duration and duration of surgery did not correlate, a possible extend in operative time should be tolerated.

## P 24

### The Cost of a Dural Tear in Operative Treatment of Lumbar Disc Herniations – a Single Center Cost Analysis

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**Introduction:** Incidental dural tears (DT) are a common complication in the surgical treatment of lumbar disc herniations (LDH). Besides affecting the patient's health, DT mean a socioeconomic burden to the health care system. This single center study displays the costs of this complication. **Materials and Methods:** 165 patients who underwent primary one level nucleotomy of the lumbar spine from January 2015 to December 2018 in our clinic were included. Patients, who underwent previous surgery of the lumbar spine (n: 57), those with additional procedures (n: 29) and traumatic LDH (n: 1) were excluded. Age, height, body mass index (BMI), costs, revenues, the length of stay (LOS), ASA score, duration of surgery and intraoperative blood loss were analyzed.

**Results:** In 6 of the 165 included patients a DT occurred (3,63 %). Mean cost in patients without DT was 4319,67 € (± 1580,42 €) and with DT 6477,36 € (± 2071,97 €). The average revenue without DT was 4264,28 € (± 1019,27 €) and 4366,76 € (± 357,91 €) with DT. The average difference of cost and revenue of a patient without DT was 9,75 % of the average difference of a patient with DT (p = 0,17). The duration of surgery (p < 0,01) and the BMI (p = 0,01) were significantly higher in the group with DT. The patient's LOD was 0,93 days longer in case of a DT (p = 0,31). In four cases, complications during inpatient stay of patients without DT were observed, 2 of them were recurrent LDH (1,21 %) and 2 were epidural hematomas (1,21 %). Patients with DT were immobilized for 3 days after surgery and treated with cefazolin. Intraoperatively, materials such as suture material, fibrin sealant, resorbable hemostypticum, dural regeneration matrices and once dexamethason were used and applied.

**Discussion:** Dural tears lead to significantly longer operative times and are significantly more often associated with a high BMI. The average LOS was not significantly higher in patients with DT. In addition to high working expenses of operating rooms (duration of surgery) not only cost of supplies, but also opportunity costs due to missing of the full use of resources such as in-hospital beds or capacity of operating rooms should be considered. In consequence of different regional accounting processes the German DRG-system is hardly transferable to other countries. Nevertheless, additional costs in the group of DT can be assumed due to the fact that with a higher LOS, even if it is not significant, additional resources are used resulting in additional costs, that may not be listed and thus not covered by the DRG.

## P 25

### The prevalence of redundant nerve roots in patients with lumbar spinal stenosis is body-position dependent: a retrospective observational study with repeated measures design in an upright MRI scanner

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**Introduction:** Redundant nerve roots (RNRs) are a negative prognostic factor in patients with central lumbar spinal stenosis (LSS). Forty percent of candidates for surgical decompression show RNRs (RNR+) on preoperative conventional magnetic resonance imaging (MRI). We investigated the prevalence of RNRs in three functional postures (Standing, Neutral sitting and Flexed sitting) with an upright MRI (upMRI).

**Methods:** A retrospective database-based study with a repeated measures design. Thirty surgical candidates underwent prospectively an upMRI. Sagittal and axial T2-weighted images of the three functional postures were evaluated (Fig. 1). The segmental length of the lumbar spine (sLLS), the lordotic angle (LA) and the dural cross-sectional area (DCSA) were measured in each body position. Generalized linear mixed models were carried out. The 0.05 level of probability was set as the criterion for statistical significance.

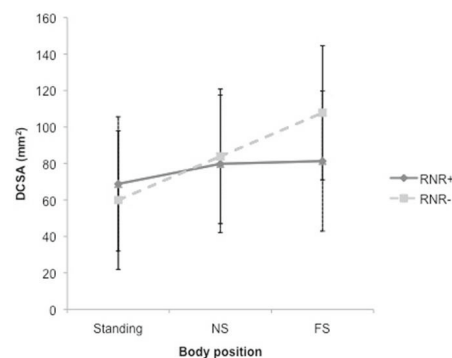
**Results:** The mean age of the patients was  $68.2 \pm 8.0$  years. There was a statistically significant association between body position and the prevalence of RNRs on the MR images ( $\chi^2 = 28.3$ ;  $p < 0.001$ ). The prevalence of RNRs decreased by 66.6% with the change from Standing to Neutral sitting and decreased further by 37.5% with the change from Neutral sitting to Flexed sitting. Accordingly, the distribution between RNR+ (80%) and RNR- (20%) in the standing position was inverted in the Flexed sitting: RNR+ (16.7%) and RNR- (83.3%). The sLLS increased significantly from Standing to Neutral sitting in both RNR groups ( $p < 0.001$ ). The increase from Neutral sitting to Flexed sitting was only significant ( $p < 0.001$ ) for the group without RNRs (RNR -). The LA decreased significantly for both RNR groups from Standing to Flexed sitting ( $p < 0.001$ ). The DCSA increased significantly in the RNR- group ( $p < 0.001$ ) but not in the RNR+ group ( $p = 0.9$ ) (Fig.2).

**Conclusions:** RNRs are a functional feature of lumbar spine stenosis and are body-position dependent. The DCSA is the most important factor regulating the prevalence of RNRs. RNRs are diseased cauda nerve roots that strongly affect patients with LSS. The analgesic trunk flexion during walking, the relief provided by sitting or stooping and the progressive shortening of the walking distance are self-help mechanisms that decrease the prevalence of RNRs.

**Fig. 1** Sagittal T2-weighted Upright MR images of a single patient: (a) in Standing position with evidence of serpentine-shaped RNRs (white arrows) cranially and caudally from the stenotic level L3/L4; (b) in Neutral sitting position with RNRs (white arrow) only caudally from the stenotic level; and (c) in Flexed sitting position with no evidence of RNRs.



**Fig. 2** Estimated mean DCSA (mm<sup>2</sup>) with standard error of the mean (SEM) for RNR groups across body positions (NS= Neutral sitting; FS= Flexed sitting).



## P 26

**Transforaminal endoscopic implantation of stimulation leads targeting the dorsal root ganglion for treatment of mono-/polyradicular pain**\*G. Bara<sup>1</sup>, J. Maciarczyk<sup>1</sup>, C. Meyer<sup>2</sup>, S. Schu<sup>3</sup>, J. Thissen<sup>2</sup><sup>1</sup>Universitätsklinik Bonn, Neurochirurgie, Bonn, Germany<sup>2</sup>Schön Klinik Düsseldorf, Fachzentrum Rücken und Wirbelsäule, Düsseldorf, Germany<sup>3</sup>Sana Kliniken Duisburg, Neurochirurgische Klinik, Duisburg, Germany

**Introduction:** Stimulation of the dorsal root ganglion is an emerging therapy for pain conditions involving one or more distinct nerve roots. Due to the percutaneous implantation technique and lead design it is a challenge to use in patients who underwent surgical procedures in the targeted spinal levels due to epidural scar formation. In this technical note we describe the first successful endoscopic lead placement in patients with prior discectomy or fusion surgery suffering from postlaminectomy syndrome and severe radicular pain.

**Methods:** Patients were selected who underwent failed attempts of traditional percutaneous implantation of leads for spinal cord stimulation via the interlaminar approach. Endoscopically a cylindrical lead was placed transforaminally. Hereby the foramen intervertebrale was punctured with a spinal needle, followed by dilatation of the tract in Seldinger technique. Then, the foramen was inspected under the endoscope, scar tissue was partially removed and a curved probe was inserted via the foramen into the spinal canal. A cylindrical lead was then placed via this working channel into the spinal canal covering the dorsal root ganglion itself and recessal nerve root fibres. Leads were kept in place via anchoring on the fascia and relief loops. Burst Stimulation was applied to prevent recruitment of motor fibers.

**Results:** 13 patients were implanted with this technique so far with excellent paraesthesia coverage of the pain area and subsequent pain relief. In six months follow up lead location and paraesthesia coverage was stable.

**Conclusion:** The technique of endoscopic lead placement targeting the dorsal root ganglion should be taken into consideration following unsuccessful traditional lead placement.

## P 27

**Vertebral disk morphology of the lumbar spine: a retrospective analysis of collagen-sensitive mapping using dual-energy computed tomography**\*F. Schömig<sup>1</sup>, M. Pumberger<sup>1</sup>, Y. Palmowski<sup>1</sup>, A. K. Ditzges<sup>2</sup>, T. Diekhoff<sup>2</sup>, F. Göhler<sup>2</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Centrum für

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**Introduction:** Lumbar radiculopathy is one of the most common symptoms caused by degenerative spinal disease [1]. Diagnosis mainly relies on clinical findings and magnetic resonance imaging (MRI). After failed conservative treatment, local pain injections are indicated as a diagnostic and therapeutic approach. More recently, dual-energy computed tomography (DECT) has been introduced for visualization of the disk [2]. This study's aim therefore was to investigate the diagnostic accuracy of collagen-sensitive maps based on DECT for the detection of lumbar disk pathologies in a feasibility setting.

**Materials and Methods:** We retrospectively reviewed MRI and DECT datasets from patients who underwent periradicular therapy (PRT) of the lumbar spine from June to December 2019. Disks of vertebral segments treated by PRT were defined as target disks and morphologically normal disks as reference disks. Three readers scored DECT collagen maps and MRI for the presence and type of disk pathology and for facet joint arthropathy. A comprehensive granular scoring system was developed and implemented to assess disk morphology. Contingency table analyses were performed to determine diagnostic accuracy. Correlation between sum scores of anteroposterior disk displacement was determined by calculation of

Spearman's  $\rho$ . Interrater agreement was evaluated by computing intraclass correlation coefficients (ICCs).

**Results:** In 21 disks in 13 patients, DECT had a sensitivity of 0.87 [0.60–0.98] and specificity of 1.00 [0.54–1.00] for the detection of disk pathology. While interrater agreement for the subtype of disk pathology was low (ICC, 0.321 [–0.136–0.659]), agreement for anteroposterior disk displacement was good (ICC, 0.963 [0.909–0.985]). Spearman's  $\rho$  was 0.9 ( $p < 0.001$ ).

**Discussion:** DECT showed high sensitivity and specificity in detecting lumbar disk pathologies using MRI as standard of reference. Previous studies have shown high diagnostic accuracy of DECT in detecting disk injuries [3]. This fairly new technique may therefore provide useful diagnostic information in patients undergoing CT for other indications, e.g. for trauma imaging or CT-guided interventions, or with contraindications to MRI.

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## P 28

**Hemochromatosis as a competing cause for occupational lumbar disc disease**\*J. Hettfleisch<sup>1</sup><sup>1</sup>medexpert, Weiterstadt, Germany

**Introduction:** The consensus recommendations for the BK 2108 (Bolm-Audorff et al. 2005) are listing various competing causes of damage to the texture of a lumbar intervertebral disc and provide a detailed scientific justification for each. Haemochromatosis is not mentioned – although there is evidence that this also leads to a fateful disc texture disorder.

**Case Report:** A 46-year-old man claims a job-related, intervertebral disc disease in the area of his lumbar spine. Only at the age of 31 years is he diagnosed with hemochromatosis – and therefore referring to this only since then is he treated effectively. At the age of 35, he undergoes spondylolysis C6/7 due to a slipped disc in his cervical spine (Figure 1). As so often, the affected administration does not determine the relevant technical working conditions – which is why in his case the load-conforming damage pattern is of particular importance (Figure 2). If his hemochromatosis had not been taken into account, the consensus recommendations (Bolm-Audorff et al 2005) would have resulted in one of the cases B 3 – B 7, for which a causal relationship with occupational stress was disputed within the working group at the time. However, if haemochromatosis is taken into account as a competing cause of damage, a constellation B 10 **Results:** A presumed disc-related disease affects one or both of the lowest lumbar discs, the extent of the disc damage corresponds to at least *Chondrosis grade II* and there is no concomitant spondylosis. In this respect, the consensus recommendations (Bolm-Audorff et al. 2005) consider the connection with a disc-damaging occupation to be "not likely".

**Conclusion:** Haemochromatosis is based on a genetic defect – which means that the health disorder in this case has remained undetected and untreated since birth and until diagnosis. Even if such a disease is not explicitly treated in the consensus recommendations (Bolm-Audorff et al. 2005), Bywaters and colleagues (1971) as well as Richards and Hamilton (1976), among others, have pointed out that it leads to a deposition of minerals in the interior of the intervertebral disc – accompanied by a texture disorder. This condition can therefore very well be regarded as a competing cause of intervertebral disc damage.

Fig. 1



Fig. 2



## P 29

### Spinal surgery shows a high complication rate in traumatic spinal cord injury of the thoracic and lumbar spine – a quality and risk analysis of the initial treatment

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**Introduction:** Analyses of complications after spinal surgery for fractures in the thoracic and lumbar spine with spinal cord injuries (SCI) are crucial to reduce complication rates and achieve a better outcome for patients. Due to different definitions of spinal surgical adverse events (SSAE), the heterogeneous patient population and different outcome measurements of SCI, only few data have been published so far.

The aim of the present study is the analysis of SSAE of surgery for SCI in the thoracic and lumbar spine with special focus on complications directly related to the initial surgical procedure, treatment times and costs.

**Methods:** In a monocentric study, medical parameters of patients with traumatic spinal cord injury in the thoracic and lumbar spine

and spinal surgery from 2011 to 2017 were analysed (ethics committee EA2/015/15). Cases with defined criteria for a SSAE were compared with the total population with respect to our questions in adjusted statistical models.

**Results:** A total of 141 patients were included, of which 26% (n=37) had at least one SSAE. The most frequent SSAE was insufficient decompression (15%) followed by incorrect positioning of the osteosynthesis material (9%) and wound infection (4%). SSAE occurred significantly less ( $p<0.001$ ) when surgery was performed by certified spinal surgeons. There was a significant increase in SSAE in both elderly and male patients (Figure 1). After a thoracic or lumbar spine SSAE, the hospital stay was extended from 67d (IQR 42–95d) to 87d (IQR 63–108d) ( $p=0.036$ ). In the final result, however, a SSAE does not lead to increased treatment costs (total treatment costs in €\*1000, median: without WSK 50.9 vs. with WSK 51.1; n.s.). There were no differences in the treatment-related complications (pneumonia, urinary tract infection, decubitus).

Regardless of the SSAE, age and sensorimotor complete spinal cord injury (AIS A) were a risk factor for the absence of AIS conversion. Age has an influence on prolonged treatment time and death in initial treatment (Figure 2).

**Conclusion:** In comparison to the analyses from current reviews, initial operations on fractures with spinal cord injury in the thoracic and lumbar spine area show a similarly high complication rate, which can be explained by the complexity of the interventions and the severity of the injury. The operations should be performed by certified spinal surgeons. In the context of multimodal therapy, possible complications should be considered, especially in older patients and an initially complete spinal cord injury.

Fig. 1

Total sample					
Variable	Group without SSAE	n	Group with SSAE	n	SMD (95% CI)
Age, Median (IQR)	46.2 (34.1–66.4)	104	51.3 (44.5–71.2)	37	0.24 (-0.22–0.69)
Gender, female (%)	34 (22.7)	104	5 (13.5)	37	-0.63 (-1.19–(-0.06))
BMI, Median (IQR)	24.8 (22.5–27.8)	101	25.2 (22.3–27.8)	37	-0.01 (-0.38–0.37)
AIS at admission, A : B : C : D (%)	48 : 8 : 9 : 39 (46.2 : 7.7 : 8.7 : 37.5)	104	20 : 2 : 4 : 11 (54.1 : 5.4 : 10.8 : 29.7)	37	-0.16 (-0.53–0.22)
Neurological level at admission, th : l : s (%)	51 : 48 : 5 (49 : 46.2 : 4.8)	104	22 : 11 : 4 (59.5 : 29.7 : 10.8)	37	-0.07 (-0.45–0.3)
CCI, Median (IQR)	0 (0–1)	104	0 (0–1)	37	-0.1 (-0.48–0.28)

Values in bold typeface represent effect differences between groups.  
SSAE, spinal surgery adverse events; AIS, ASIA Impairment Scale; CCI, Charlson Comorbidity Index; IQR, interquartile range; SMD, standardized mean difference

Fig. 2

Total sample n=135		
Dependent variable: AIS-conversion (no=0, yes=1) Nagelkerkes R <sup>2</sup> =0.33		
Covariates	Odds Ratio (95% CI)	p-value
Age (per one year increase)	0.96 (0.93–1)	0.031
Sex (female=0, male=1)	1.6 (0.46–5.54)	0.457
AIS (A=0, B/D=1)	8.8 (2.91–26.63)	<0.001
Primary surgical care at trial center (0=No, 1=Yes)	0.87 (0.29–2.6)	0.8
CCI (per one point increase)	0.61 (0.28–1.32)	0.206
surgical complications (0=No, 1=Yes)	1.53 (0.51–4.59)	0.445
Dependent variable: death (no=0, yes=1) Nagelkerkes R <sup>2</sup> =0.33		
Covariates	Odds Ratio (95% CI)	p-value
Age (per one year increase)	1.56 (1.05–2.31)	0.028
Sex (female=0, male=1)	1.92 (0.01–301.3)	0.801
AIS (A=1, B/D=0)	29.19 (1.835–83)	0.05
CCI (per one point increase)	1.7 (0.94–3.1)	0.081
surgical complications (0=No, 1=Yes)	0.09 (0.3–62)	0.199

## P 30

**Influence of operative timing on the outcome after kyphoplasty**

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**Background:** The kyphoplasty is one of the surgical standard treatments of vertebral compression fractures. It offers quick pain relief and the possibility to restore the vertebral body height. Currently, it is mainly considered for patients with persistent pain under conservative treatment. Therefore, most surgeries are performed several weeks after the fracture. However, it is unclear if a delay of the surgical treatment compromises the potential height restoration. The aim of this study was to clarify the relationship between the operative timing and the postoperative radiological as well as clinical outcome after kyphoplasty.

**Methods:** We included patients who received kyphoplasty of a single vertebral fracture between January 2014 and December 2018. Patients were divided into three different groups with acute (< 2 weeks), subacute (2 – 6 weeks) or chronic (> 6 weeks) fractures depending on the interval between the fracture and surgery. The anterior and middle vertebral body height as well as the local kyphotic angle (LKA) were measured on pre- and postoperative X-ray images. Additionally, clinical parameters including pre- and postoperative pain scores (VAS at rest and in motion) as well as use of analgesics (according to WHO analgesic ladder) were obtained from patient records. Statistical analysis was performed to evaluate pre- and postoperative differences of the different parameters as well as differences between the three groups.

**Results:** 230 patients were included in the study. Of these, 100 had acute fractures, 93 had subacute fractures and 38 had chronic fractures. All three groups improved significantly postoperatively regarding anterior and middle vertebral body height (all groups:  $p < 0.001$ ), LKA (acute:  $p < 0.001$ ; subacute:  $p < 0.001$ ; chronic:  $p = 0.046$ ) and pain. Use of analgesics decreased significantly after the intervention for the acute and subacute groups, but not for the chronic group. The reposition of the LKA was significantly better for acute and subacute fractures as compared to chronic fractures.

**Conclusion:** Kyphoplasty offers the possibility to restore the vertebral body height and to reduce pain for both fresh and older fractures. The achievable LKA correction is significantly higher if surgery is performed within the first 6 weeks after fracture.

## P 31

**"Kyphoplasty Restores the Global Sagittal Balance of the Spine after singular vertebral compression Fracture"**

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**Introduction:** Kyphoplasty is the standard surgical treatment for vertebral compression fractures. Yet little is known about the long-term benefits compared to conservative treatment. One benefit of kyphoplasty could be the restoration of the sagittal profile due to the restoration of the vertebral body height. In this study we aimed to clarify the influence of kyphoplasty on the sagittal profile of the spine as well as the relation between posture improvement and pain relief.

**Material & Methods:** Patients who underwent kyphoplasty for treatment of single vertebral compression fractures between January 2014 and December 2018 were included in this study. Various radiological parameters of the sagittal profile (LKA, GA, CA, SVA, SS, PT, LL, TLSL, TLA and TK) were measured on whole spine standing radiographs pre- and postoperatively. Furthermore, clinical parameters including pain scores on visual-analogue scale (VAS) in rest and motion and use of analgesic (WHO-scale) were obtained from patients' medical records. Pre- and postoperative radiological as well as

clinical parameters were compared. Moreover, the correlation between changes of SVA and changes of local kyphotic angle or VAS was examined.

**Results:** 73 patients met the inclusion criteria and were included in this study. The clinical parameters as well as various radiographic parameters (lumbar lordosis, sagittal vertical angle, local kyphotic angle, Gardner- and Cobb angle) improved significantly postoperatively. The improvement of SVA correlated significantly with the correction of the body height (LKA). No significance could be shown for SVA improvement and postoperative pain relief.

**Discussion:** In this study we could show, that kyphoplasty helps to restore the global sagittal balance of the spine after vertebral compression fractures. The correction of the sagittal profile seems to depend on the correction of the local kyphotic angle but does not correlate with postoperative pain relief. With these results it is shown that kyphoplasty plays an important role in the treatment of vertebral compression fractures.

## P 32

**The spinal surgery and initial treatment of traumatic, inflammatory and tumor-related paraplegia – a descriptive analysis of the interdisciplinary initial treatment**

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**Introduction:** The initial treatment of spinal cord injury (SCI) is based on the concept of comprehensive and interdisciplinary care. At the beginning of treatment, spine surgery poses a major challenge for spinal surgery centers due to the severity and acute SCI. Due to the various causes of SCI, the acute treatment of traumatic, inflammatory and tumor-related SCI differs significantly. Every year 1000 acute traumatic and non-traumatic SCIs occur in Germany. The aim of the study is the descriptive analysis including comparison of complications, length of stay and health care costs.

**Methods:** Within the framework of monocentric health care research, medical and health economic parameters of patients with acute spinal cord injuries were analysed from 2011 to 2017 (ethics vote EA2/015/15). A total of 365 patients (traumatic  $n = 246$ ; inflammatory  $n = 64$ ; tumorous without primary bone tumors  $n = 55$ ) were included and evaluated using descriptive methods.

**Results:** In comparison, traumatic, inflammatory and tumor-related spinal cord injury (SCI) differ in age, gender distribution and neurological status (Figure 1). Characteristic for the traumatic SCI were the younger age (mean 62 years) and the high proportion of complete cervical SCI at admission (AIS A 42% of all cases; ASIA Impairment Scale) (Figure 1). In most cases, spinal surgery was performed (traumatic: 94%, inflammatory: 84%, tumor-related: 87%). Spinal surgical complications were less severe in the inflammatory and tumor-related SCI (9%) than in the more complex spinal injuries after a traumatic SCI (24%). Compared to the other SCIs, tumor-related SCIs resulted in fewer urinary tract infections, pneumonias and multi-resistant pathogen detection due to the predominantly incomplete SCI and non-inflammatory cause (Figure 1). Inflammatory (19%) and tumour-related SCIs (16%) have the highest death rate in primary treatment, with patient willingness documented in over 85% of these cases. For traumatic SCI, the length of stay (mean 80 days) and the treatment costs (mean 57.200 €) were highest (Figure 2).

**Conclusion:** Spinal surgery is at the beginning of the treatment of acute SCI and must be carried out with few complications, despite the severity of the illness and the emergency situation. The aetiology of the SCI must be taken into account in therapy planning. The centres for spinal surgery and spinal cord injuries must work closely together to achieve optimal patient care with a low complication rate.

Fig. 1

Baseline Charakteristika	Traumatisch n=246	Entzündlich n=64	Tumorös n=55
Alter, Median (IQR)	62 (43–77)	72 (62–80)	68 (61–75)
Geschlecht, weiblich, %	29	47	31
AIS bei Aufnahme, A : B : C : D, %	42 : 6 : 13 : 36	11 : 8 : 17 : 50	22 : 7 : 16 : 55
neurologisches Niveau bei Aufnahme, cervikal : thorakal : lumbosakral (%)	59 : 20 : 18	17 : 16 : 52	24 : 51 : 25
Komplikationsrate	Traumatisch n=246	Entzündlich n=64	Tumorös n=55
Wirbelsäulenchirurgische Komplikationen, Ja in %	24	9	9
Harnwegsinfektion, Ja in %	74	45	13
Lungeninfektion, Ja in %	50	39	7
Dekubitus, Ja in %	19	16	13
Thrombose, Ja in %	7	0	0
heterotope Ossifikation, Ja in %	2	0	0
Multiresistente Besiedlung, Ja in %	31	33	7
Tod in der Erstbehandlung, Ja in %	8	19	16

Fig. 2

	Traumatisch n=246	Entzündlich n=64	Tumorös n=55
Gesamtaufenthalt in Tagen, M (SD)	79.8 (88.8–113.5)	14.3 (22.2–86.4)	27 (17–52)
OP-Kosten in €*1000, M (SD)	5.7 (3.1–8.4)	5.3 (3.8–8.2)	5 (2.6–6.9)
OP-Kosten in €*1000, M (SD)	57.2 (33.8–97.8)	43.5 (24.8–80)	19.3 (13.4–27)

## P 33

**Diagnosis, treatment and outcome following traumatic atlanto-occipital dislocation**M. Kreinest<sup>1</sup>, L. Hörnig<sup>1</sup>, P. A. Grützner<sup>1</sup>, \*M. K. Jung<sup>1</sup><sup>1</sup>BG Klinik Ludwigshafen, Ludwigshafen, Germany

**Introduction:** Traumatic atlanto-occipital dislocation (AOD) is a very rare traumatic injury of the cervical spine with an incidence of approximately 1% of all trauma patients (1). Mortality for patients with AOD is up to 79% in some studies (2). In recent years, the improvement and standardization of pre-hospital emergency trauma care has led to an increased number of patients reaching the hospital alive (3, 4).

This study evaluated the diagnosis, treatment and clinical outcome of patients with traumatic AOD.

**Material/Methodology:** All patients treated with traumatic AOD in our level I Trauma Center between January 2012 and December 2019 (Condylar Sum [CS]  $\geq 4.2$  mm) were included. Patient demographics, preclinical data, treatment data and concomitant injuries were documented. The following radiological parameters have been analyzed retrospectively: Basion-Dens-Interval (BDI), Basion-Axis-Interval (BAI), Power's Ratio (PR) und Lee's X-lines (X-Line). The clinical and especially the neurological outcome of the patients were evaluated.

**Results:** 12 patients could be included in this study (8 male, 4 female). As accident mechanisms, there were falls from great heights and car accidents (high-energy trauma) as well as falls at home (low-energy trauma). The mean CS was  $10.3 \pm 9.8$  mm. The remaining measured values showed pathological values in only 16.7% (BAI and PR) and 33.3% (ADI and X-Line).

A total of four patients died before surgical stabilization could be achieved. A total of 3 patients could be treated with a dorsal occipito-cervical fusion. A further 5 patients were not fit for surgery due to poor cardiovascular condition and had to be treated conservatively. A total of 5 patients died during inpatient treatment (41.7%). The follow-up period was 6.7 months (1–24). The GCS was 15 in all patients. Three patients had persisting neurological deficits.

**Discussion:** Patients with a traumatic AOD should be treated according to current guidelines during emergency care. The further clinical treatment strategy should be determined individually, taking into account the concomitant injuries and the patient's cardiopulmonary stability. Thus, in the present study the survival rate was increased to 58.3%.

**Literature:**

- (1) Chaput et al (2011) J Trauma 71
- (2) Dickman et al (1993) J Spinal Disord 6
- (3) Horn et al (2007) J Neurosurg Spine 6
- (4) Krotbeck et al (2008) J Trauma 64

## P 34

**Presentation and surgical management of the cervical spine fractures in ankylosing spondylitis – a study of 55 patients**\*R. Bahrami<sup>1</sup>, \*M. Alhashash<sup>2</sup>, H. Böhm<sup>1</sup>, M. Shousha<sup>2</sup><sup>1</sup>Zentralklinik Bad Berka, Wirbelsäulenchirurgie, Bad Berka, Germany<sup>2</sup>Zentralklinik Bad Berka, Germany and Alexandria University, Egypt, Spine Surgery, Bad Berka, Germany

Ankylosing spondylitis is associated with spine deformity and spontaneous fusion. In the cervical spine, fractures may occur after mild trauma or even without a history of trauma. The clinical presentation is different from the fractures in the normal cervical spine. In this work, the clinical presentation and the surgical treatment of cervical spine fractures in ankylosing spondylitis were evaluated.

**Patients and Methods:** In our department, the clinical and the surgical data of all operated patients are prospectively collected. A retrospective analysis of this data revealed a case series of 55 cervical spine fracture patients with ankylosing spondylitis who were surgically treated between 1994 and 2015. The clinical presentation and the surgical treatment, as well as the long term results, were analyzed.

**Results:** There were 3 females and 52 males, with a mean age of  $58 \pm 9.5$  years. History of trauma was recorded in only 20 patients (36%). The presentation was a pain in all patients, worsening of the visual axis and increased cervical kyphosis in 19 (33%), and neurological deficit in 16 (29%). The surgical treatment was done after a mean of 170 days (1 day – 2 years) after the beginning of the symptoms.

The posterior only approach was performed in 25 patients, in 13 patients posterior-anterior approach was used, in 8 patients with anterior stenosis an anterior-posterior approach was used, in 9 patients a posterior-anterior-posterior approach was used, and only in 2 patients, an anterior approach was used. The mean operation time was 246 minutes (195 – 420). The mean blood loss was 780 ml (450 – 2500). Posterior fixation was performed over a mean of 7.5 segments (4 – 12).

In 8 patients wound healing was delayed with wound revision. The loss of correction with re-operation was in 2 patients. Neurological improvement was recorded in 12 patients, at the end of the follow-up, (Mean of 72 months) 4 patients did not show neurological improvement. A mean correction of 22.5 degrees was achieved during surgery (5 – 35).

**Conclusions:** Patients with ankylosing spondylitis may have cervical spine fractures without a history of trauma. Worsening of the deformity, increased pain intensity, and neurological deficit are warning signals for the possibility of fracture in ankylosing spondylitis patients. The posterior approach is effective in the case of cervical spine fractures in ankylosing spondylitis. Correction of the deformity can be safely performed during surgical management. The main complication is delayed wound healing.

## P 35

**Bilateral avulsed occipital condylar fracture extending to anterior rim of foramen magnum with concomitant anterior C1 ring fracture resulting in atlanto-occipital and atlantodental dislocation: Case report and surgical management**\*P. Oni<sup>1</sup><sup>1</sup>Klinikum Dortmund, Neurochirurgie, Dortmund, Germany

**Introduction:** Bilateral occipital condyle fracture (B-OCF) with anterior C1 Ring fracture resulting in simultaneous atlanto-occipital (AOD) and atlantodental dislocation (ADD) is a rare and potentially lethal injury<sup>1,2</sup>. The case of an accident victim and the surgical management is reported.

**Material & Methods:** A 33-year old man suffered bilateral occipital condyle fractures (B-OCF) with fracture of the anterior

rim of the foramen magnum and ventral C1-arch resulting in AOD and ADD after a motorcycle accident at 70 km/h. The Data of the clinical course, the surgical procedure as well as CT and X-ray images were evaluated. The pre and postoperative basion-axial interval (BAI), basion-dental interval (BDI) and anterior atlantodental interval (AADI) were measured and used in detecting atlanto-occipital and atlantodental dislocation.

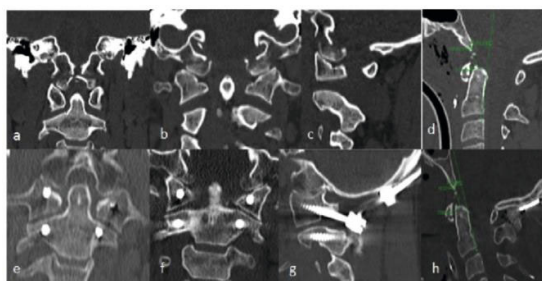
**Results:** On arrival of the emergency team at the accident scene the patient had a Glasgow coma score of 14 with slightly altered mental status. Massive bleeding from the oral cavity necessitated protective intubation. A cervical collar was placed. Craniocervical CT revealed occipital subgaleal hematoma without intracranial injury, bilateral occipital condyle fracture with fracture of the anterior rim of the foramen magnum and ventral C1-arch resulting in AOD (BDI=18.3 mm; BAI = 15 mm) and ADD (AADI =3.7 mm) (Pic.1:d) as well as ventral craniocervical epidural hematoma. After initial oral surgery to stop the bleeding from the oral cavity, occipitocervical fixation C0-C1-C2 was performed on the second day of admission. The Postoperative BDI, BAI and AADI were 18.2 mm, 5.8 mm and 2.5 mm respectively (Pic.1:h). After 5 weeks of inpatient treatment of the polytraumatized patient, including placement of a tracheostomy tube, the patient was discharged without any sensory or motor deficits, in particular no cranial nerve failures. CT examination 6 months post surgery revealed good bony consolidation so that the craniocervical implants could be removed. Postoperative cervical spine X-ray showed preservation of normal pain free motion at C0-C1-C2 motion segments (Pic.2).

**Discussion:** Posterior fixation C0-C1-C2 was the most effective procedure to address the complex craniocervical fracture resulting in AOD and ADD in this case<sup>1,2</sup>. Implant removal to free the C0-C1-C2 motion segments after bony consolidation of the fracture was deemed necessary in this young patient. This case highlights the importance of good prehospital management of accident victims as well as early diagnosis and treatment of complex craniocervical injuries.

Reference.

1. Kasliwal MK et al. Occipitocervical Dissociation-Incidence, Evaluation, and Treatment. *Curr Rev Musculoskelet Med*.2016 Sep;9(3):247-54.
2. Hall GC et al. Atlanto-occipital dislocation. *World J Orthop* 2015 March 18; 6(2): 236-243

**Fig. 1**



Pic. 1: preop (a-d) and postop (e-h) reconstructed CT respectively

**Fig. 2**



Pic. 2: Cervical X-ray (a) after C0-C1-C2 fixation, (b and c) in ante- and retroflexion 2 months after implant removal

### P 36

#### Improvement of the anterior vertebral body fracture reconstruction using a dorsal reduction tool

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**Introduction:** Vertebral body fractures in the thoracolumbar region often lead to kyphotic malalignment. Therefore, surgical treatment aims for reduction of sagittal alignment and reconstruction of the anterior column. Sufficient elevation of the anterior edge of the vertebra might possibly prevent the necessity of additional anterior stabilization or vertebral body replacement. The purpose of this study was to examine whether greater anterior reduction can be achieved by utilizing a reduction tool and whether postoperative loss of vertebral height can be reduced.

**Material/Methods:** Between 2015-2020, 90 patients with A3/A4 fractures of the thoracolumbar region underwent posterior bisegmental stabilization in one level I trauma center. A reduction tool (Nforce, Medtronic) (IG) was utilized in 37 cases. 53 patients were only reduced through intraoperative positioning and served as control group (CG).

To assess the bony reduction result, the vertebral kyphosis angle was measured pre-/postoperatively and after osseous consolidation. Additionally, the percentage of height reduction was determined by measuring the anterior and posterior edge of the fractured vertebral body on X-Ray and CT images. Clinical outcome was assessed by Ostwestry Disability Index (ODI).

**Results :** No differences in terms of gender and comorbidities were found between the two groups. Mean age was 42 years in the IG and 48 years in the CG (p=0.02). At the time of fracture, the anterior vertebral height was reduced by 31% in the IG and 26% in the CG (p=0.04), resulting in a kyphosis angle of 15° vs. 12°, respectively (p=0.01).

Intraoperatively, the anterior column was reduced by 20% (CG 12%, p<0.001) with the reduction tool and the kyphosis angle corrected by 9° (CG 5°, p<0.001), so that initially greater kyphosis could be compensated. Postoperatively, there were no significant differences in height reduction (p=0.09) and angle (p=0.2).

Despite greater postoperative loss of reduction for patients in the IG with 13% vs. 8% in the CG and a loss of correction of the vertebral angle in the IG with 5° vs. 3° (p<0.05), the overall reduction from time of fracture to osseous consolidation resulted in better reconstruction of the anterior column with 8% and correction of the angle by 4° in the IG compared to the CG with 3% and 2°, respectively (p<0.05).

There was no difference in the clinical outcome determined by the ODI (IG=17% vs. CG=25%; p=0.2).

**Discussion:** Utilizing a reduction tool during posterior stabilization of vertebral body fractures in a suitable collective of young patients with good bone quality and severe fractures may lead to a significantly better reconstruction of the ventral column of the fractured vertebral body and angle correction. Therefore, additional surgery or vertebral body replacement may be possibly prevented.

### P 37

#### Does anticoagulation have an influence to the outcome after spinal fractures in patients with ankylosing spondylitis?

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**Introduction:** In comparison to the normal population, there is an accumulation of various comorbidities in ankylosing spondylitis patients (SAP). In particular, SAPs have an increased risk of cardiovascular disease, hypertension and malignant diseases. Does the use of anticoagulants lead to a worsened peri- and postoperative outcome in SAP?

**Material and Method:** Retrospective analysis of all spinal surgery patients with ankylosing spondylitis or DISH from 2008 to 2019 with regard to comorbidities and peri- and postoperative complications.

**Results:** During the 11-year study period, 152 patients with SP after trauma (AO type B or C) were treated surgically at the spinal column. For 108 patients a usable complete data set was found. 57% (n=61) of the patients took blood-thinning long-term medication at the time of admission. The most frequent concomitant diseases were arterial hypertension (57%; n=55), diabetes (37%; n=40) and arrhythmias (17%; n=18). In 8% (n=9) of the patients, paraplegia was found preoperatively, 7 of these patients had an ongoing therapy with anticoagulants. Severe intraoperative complications (resuscitations, unstable cardiovascular situation) were found in 16 % (n=20) patients. In 7 % (n=9) bleeding complications led to an early termination of surgery. A significantly higher blood loss ( $p<0.001$ ) was observed in the comparison of SAP with blood thinners vs. without. The mortality rate in the peri- and postoperative course was 14 % (n=18).

**Summary:** Anticoagulant drugs have an influence on the outcome of SAP. However, these were found in the majority of patients with neurological disorders. In addition, there was a significantly higher blood loss. SPA also showed a high rate of co-morbidities in our study, especially cardiovascular diseases, which required the use of anticoagulants. In order to reduce bleeding complications, we therefore recommend specific coagulation management for preoperative optimization, if justifiable.

### P 38

#### The "real" SCIWORA in children and adolescents – a challenge for patient and physician

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**Introduction:** The SCIWORA Syndrome (Spinal Cord Injury Without Radiographic Abnormalities) is an overall rare but potentially severe injury with a peak in childhood and adolescence. With a better understanding of injury patterns and advances in MRI, there is an ongoing discussion regarding the current definition of SCIWORA. There are only a limited amount of studies dealing with the "Real SCIWORA" a clinical picture of neurologic deficits on clinical examination but an absence of abnormalities of the spinal cord on plain radiographs, computed tomography scans, and even MRI. The purpose of this study was to characterize patients with "Real – SCIWORA", show treatment algorithm, and short-term outcome of the patients.

**Methods:** In a retrospective analysis, we evaluated all patients who were admitted to our level I trauma center between 2007-2019. Inclusion criteria were: age up to 24 years, neurologic deficit after trauma, and a lack of pathological findings in spinal MRI. We identified 33 patients meeting the inclusion criteria. We performed an evaluation of all clinical and radiological parameters based on the patient's records.

**Results:** All patients were managed according to ATLS guidelines in our resuscitation room. An MRT of the whole spine was made to exclude structural damage of the spine. The mean age at injury was 15.4 years ( $\pm 5.3$ ). Analysis of the mechanism of injury showed that in 21 patients a low-velocity trauma was the cause of the injury and 12 patients had sustained a high-velocity trauma. None of the patients had (besides contusions) any relevant concomitant injury (e.g. extremities). All patients reported a sensorimotor deficit of the lower extremities, 8/33 had an additional impairment of the upper extremity. The mean length of hospital stay was 3.4 Tage ( $\pm 3.0$ ). There was a regression of neurologic symptoms within the first hours or a few days after injury.

**Conclusions:** The "Real SCIWORA" syndrome is a diagnosis per exclusionem and a full spinal MRI is necessary to ensure a correct diagnosis. Even though neurologic symptoms regressed in all patients, it is of utmost importance to evaluate each case to ensure the detection of structural and potentially dangerous reasons for the neurologic condition. Further clinical reevaluations and long term follow-up are recommended to prevent neurologic residue.

### P 39

#### New AOSpine Upper Cervical Classification System in comparison with the established classification systems

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**Introduction:** With the newly implemented AO Upper Cervical Spine Classification system a modern, pragmatic system has been established. To what extent the simplification is helpful or whether an adjustment of the new AO classification may be discussed, forms the question of this work.

**Material & Methods:** Retrospective analysis of 80 upper cervical spine injuries with CT/MRI diagnostics presented to 4 trauma surgeons with several years' experience to do classification and suggest treatment.

**Results:** The classification according to the known systems showed a relatively good agreement in the exact classification and therapy. The classification according to the new AO Upper Cervical Spine was simple and consistent but revealed different treatment recommendations for two subtypes (III Type A and III Type B).

**Conclusion:** The new AO Upper Cervical Spine classification system leads to a simplification. Uncertainties remain with the most frequent fractures on the upper cervical spine, the C2 fractures. These will be managed under III Type A. However, just these injuries require completely different treatment concepts. Further adaptation is required for type III B because there uncertainties regarding the therapy also remain.

### P 40

#### Occipito-cervical and C1-C2 posterior hook instrumentation: a safe and efficient alternative technique?

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**Introduction:** Nowadays, posterior occipito-cervical and C1-C2 hook instrumentation is less common than techniques using screws, which allow a high primary stability. Using hooks is simple, fast and carries a lower risk of vascular injury. The purpose of this retrospective study was to analyze clinical results, complications and sagittal occipito-cervical alignment after posterior fixation with hooks.

**Material & Methods:** 48 patients (average age 62.6 years, 21-91 years) were reexamined at an average follow-up of 21.5 (6.1-142.2) months. There were 29 C0-C4 and 19 C1-C2 instrumentations. The indications were trauma in 36 and tumor in 12 patients. Frankel and Rankin scores and complications were analyzed. Radiographic were measured preoperatively, postoperatively, at last follow-up: McGregor (MG) line slope, posterior occipito-cervical angle (POCA), C0-C2 and C2-C7 lordosis. The evolution of radiographic parameters was compared by a Student t-test and sagittal relationships were analyzed by a Pearson correlation. Fusion was analyzed on CT in 19 patients who were grafted with autologous bone.

**Results:** Two patients were Frankel C-D preoperatively, 1 Frankel D postoperatively. 87.2% were Rankin 1 preoperatively versus 46.2% Rankin 0 and 1 respectively at follow-up ( $p=0.0013$ ). Complications were: 3 cardiac, 1 neurologic, 3 wound infections, 2 deaths (tumors). There was no vertebral artery injury. In the occipito-cervical group, the MG slope decreased from 10.9° to 6.5°, the POCA increased from 104.1° to 99.2°, the C0-C2 lordosis increased from 16.8° to 25.5° and the C2-C7 lordosis decreased from 18.6° to 10.0° ( $p<0.005$ ). In the C1-C2 group, these variations were small and non-significant. There was a correlation between C0-C2 lordosis increase and C2-C6 lordosis decrease in the occipito-cervical group ( $r=-0.603$ ;  $p=0.0002$ ). 94.7% of grafted patients were fused on follow-up CT (1 occipito-cervical non-union).

**Conclusion:** The complication rate after posterior hook instrumentation was low and the fusion rate was high in the event of bone grafting. Sagittal alignment compensation mechanisms were demonstrated at the level of the non-instrumented cervical lordosis after occipito-cervical instrumentation. Therefore, the sagittal orientation by patient positioning and using an adequate surgical technique appears crucial. La technique of using supra- and sublamina hook claws appears efficient and safe when stabilizing the occipito-cervical junction or the C1-C2 complex.

Fig. 1

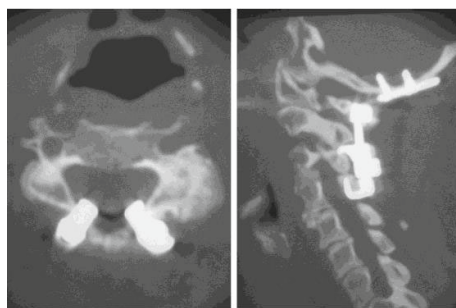
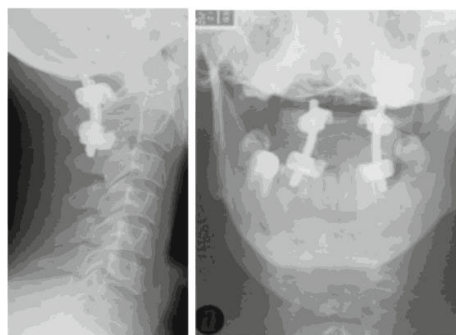


Fig. 2



## P 41

**Spine shift in the C-spine during navigated stabilisation procedures – How significant is the shift?**

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**Aims:** Large displacements of the vertebrae are often observed during stabilisation procedures on the C-spine, casting doubt on the accuracy of the navigation. In this preliminary analysis, we evaluated the movement of the vertebrae relative to the vertebra on the intraoperative CTs before (preimplant) and after (postimplant) screw implantation.

**Methods:** The intraoperative shift of 13 vertebrae in 4 patients who were operated on the C-spine using intraoperative CT and navigation in 2018 was measured in this preliminary analysis. First, the anchor vertebra (with navigation reference) was defined as a mask manually and the pre-implant and post-implant scans coregistered using the cross correlation metric and rigid transformation implemented in ANTS (Advanced Normalisation Tools) software. Subsequent vertebrae were masked manually and the registration was estimated from the anchor – registered position. The relative translation in mm (in x,y, and z axes) as well as rotation in degrees were obtained for each vertebra. All registrations were checked manually for accuracy. Vertebrae that were affected severely by metal artifacts were not included in the study. The differences in size of the displacement in three axes were evaluated using Wilcoxon signed rank test. The size of the displacement was evaluated for relationship with the relative distance from the anchor vertebra using Spearman correlation.

**Results:** The mean translation in the X axis was  $0.28 \pm 0.32$  mm, in the Y axis  $0.35 \pm 0.23$  mm and in the Z axis  $0.26 \pm 0.28$  mm. The maximal translation was 1.13, 0.74 and 1.1 mm for the three axes respectively. No rotational component could be detected in this group (all measurements  $< 1^\circ$ ). There was no correlation of the displacement with the distance of the vertebra from the anchor (Spearman's rank correlation coefficient 0.307,

p-value = 0.308). There were no differences between the size of the displacement in the three axes (X vs Y p=0.45, X vs Z p=0.78, Y vs Z p=0.38).

**Discussion:** Despite the clinically observed displacement of the vertebral bodies during intraoperative manipulation, after the external force is removed, the elastic structures of the spine seem to restore the anatomical position of the vertebrae. Displacement of up to around 1 mm of size have to be expected even with most careful implantation technique.

## P 42

**Intraoperative CT-assisted navigation in dorsal cervical instrumentation – A report on accuracy compared to conventional instrumentation regarding different pathologies**

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**Background:** While the use of intraoperative 2D C-arm fluoroscopy is still the most common clinical practice, a growing number of medical centers have introduced intraoperative CT (iCT) navigated dorsal instrumentation as a new clinical standard. Due to the close proximity of vital anatomical structures, instrumentations of the cervical spine pose an especially delicate task. Navigated approaches might therefore prove to be beneficial regarding accurate screw placement. In this study we report on accuracy of conventional versus iCT-navigated dorsal cervical spine instrumentation with focus on pedicle vs. lateral mass, as well as pathologies.

**Methods:** We analysed a consecutive series of cervical dorsal instrumentation using iCT AIRO® as well as conventional instrumentation of the cervical spine. Patients with screw placement in C1/2, subaxial and combinations were included. The underlying pathologies were also taken into account. Each screw was individually assessed by an independent observer making use of a modified Gertzbein & Robbins classification.

**Results:** In total, 39 patients were treated using iCT (224 screws; 144 pedicle, 80 lat. mass screws), while 40 patients underwent conventional instrumentation (252 screws; 24 pedicle, 228 lat. mass screws). We achieved an initial accuracy of 94.2% (n=211 screws) with iCT- and 84.9% (n=214 screws) in the conventional (C) group (p=0.005). Additionally, significant differences were found regarding the accuracy of screw placement in cases of degenerative disorders (iCT vs. C; 93.7% vs. 82.8%; p=0.01). Other pathologies (trauma, pathological fractures, infectious) showed no significant differences in accuracy. Comparisons between accuracy of pedicle or lateral mass screw placement were found not significant (neither in, nor between iCT- and C-group).

**Conclusion:** The accuracy of iCT navigated instrumentation in the cervical spine was significantly higher than conventional screw-placement, reducing the risk of harming vital anatomical structures. Although no differences were found between lateral mass and pedicle screw accuracy, the overall tendency towards the use of pedicle screws with iCT navigation is evident, possibly increasing the mechanical properties of the implanted fixateur. AIRO © iCT appears to be especially strong in elective surgery cases of degenerative spinal disorders.

## P 43

**The feasibility of C1-2 fixation in the children 5 years of age and younger: A series of 16 patients**

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**Objective:** The number of indications for fusion of the atlantoaxial region in children is rare. Instrumentation may be technically challenging in younger children, especially in the atlantoaxial region. A number of screw placement techniques have been described. However, there are few data detailing the feasibility and clinical outcome in children. In this study, the authors describe their experience using the Harms C1-2 fixation technique in 16 children 5 years of age or younger.

**Patients:** A retrospective review of all children treated with C1-2 fusion was performed. All children 5 years of age or younger with incorporation of C1 lateral mass and C2 pedicle or pars screws were included. Special focus was pointed on implant positioning.

**Results:** Sixteen children were studied (5 boys and 11 girls). The mean age at surgery was 45 months (range 10–66 months). Indications for surgery included traumatic instability (3), os odontoideum (3), deformity (4), and congenital instability (6). All C-1 mass lateral screws were placed correctly. In one case the tip of the C2 screw reached the vertebral foramen without obstructing it. There were no complications with screw placement. In one patient revision surgery due to screw loosening was performed. In two patients implant removal was performed after healing of the fracture. One patient underwent staged surgery for deformity correction. The mean follow-up duration for patients was 58 months (range 6–170 months) and all showed radiographic stability.

**Conclusion:** The C1-2 technique according to Harms is a safe technique that achieves solid fixation of the atlantoaxial complex in children with various disorders. In this study of children 5 years of age or younger, the authors found a high rate of radiographic fusion with a low rate of complications

#### P 44

##### **A case of esophageal perforation after revision anterior cervical spine surgery treated using musculus pectoralis major flap and endoluminal vacuum assisted closure**

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**Introduction:** Esophageal perforation following anterior cervical spine surgery is a rare but especially dreadful complication. Here we describe our management in a revision case with 3 level vertebral body replacement following burst fracture of C7 with incomplete paraparesis.

**Methods:** Case description and discussion with selective review of literature.

**Results:** A 44 y/o male was first admitted with incomplete paraparesis due to a flexion-distraction injury of the lower cervical spine (AOS C6-C8:B2 (C7:A4,C6:A2,N4); ASIA D). He was initially treated with anterior decompression, vertebral body replacement of C7 and anterior spondylodesis C6-Th1. During rehabilitation, neurological symptoms almost completely subsided within 12 months. However, dysphagia remained and only 3 months postoperatively and consecutively since then, implant loosening and dislocation was evident in radiological follow-ups. Combined posterior and anterior revision with spondylodesis C5-Th2 was planned. 15 months after the accident, posterior fusion C5 to Th2 was performed and five days later, anterior revision with 3 level vertebral body replacement C6 – Th1 was done. Three days postoperatively, the patient presented with swelling of the neck and massive drainage from the anterior wound. CT scans revealed perforation of the esophagus next to Th1/2 and extensive free fluids and free air. The patient was revised and perforation of the esophagus was confirmed, however, primary suture was not possible due to its position next to the cage at this level. 6 days later, a musculus pectoralis major flap transfer

was performed followed by endoscopic placement of endoluminal vacuum assisted closure therapy. Repeated replacements of the V.A.C. were done for 5 weeks until the defect was healed by granulation tissue.

In the clinical follow-ups, the last 15 months after the revision surgery, little dysphagia and no additional neurological deficit were noted. CT-scans showed bony fusion C5-Th2 and no signs of residual fistula of implant loosening.

**Conclusion :** Esophageal perforation is a rare but potentially lethal complication in anterior spine surgery. Several risk factors such as trauma, revision surgery, and multilevel vertebral body replacement were present in our case. The multi-disciplinary approach described here resulted in a favourable outcome. This method is an alternative to other flaps such as m. sternocleidomastoideus that features more muscle volume especially in the cervicothoracic region. The combination with endoluminal vacuum assisted closure which has been established for insufficiencies of anastomoses of the esophagus following resections, enabled defect healing of the esophagus while maintaining a large vertebral body replacement implant.

**Fig. 1**



#### P 45

##### **Incomplete Brown-Séquard Syndrome as Atypical Complication after Anterior Cervical Discectomy and Fusion**

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**Introduction:** Anterior cervical discectomy and fusion (ACDF) is a frequent intervention. Neurologic worsening, vocal cord paralysis and Homer syndrome are known complications. Here we describe the first case of putatively ischemic incomplete Brown-Séquard syndrome after such an intervention.

**Material/Methods:** We report a case of a 47-year old woman without known vascular or hematologic risk-factors who underwent a double level ACDF with plating from C3 to C5. After an uneventful intraoperative course, the patient developed a progressive anesthesia on the right side with a sensory level at Th3, associated with impaired hot/cold discrimination about 7h after the surgery. On the left side, a slight hemiparesis with strength M4/5 was noted. Two days later, the symptoms worsened with stinging

sensations and right hemi facial hypoesthesia in the territory of the maxillary nerve.

**Results:** An emergency CT-scan showed no displacement of the material and no hematoma. The MRI of the brain and cervical spine showed a spinal cord ischemia at the level of C3–C4, in the territory of the sulcal arteries. A treatment with oral steroids and acetylsalicylic acid was begun. After worsening of the symptoms, a second MRI of the cervical spine showed a progression of the edema, potentially involving the pars caudalis of the spinal nucleus of the trigeminal nerve. We raised the dosage of steroids, which successfully treated the facial symptoms of the patient. At three months after the intervention there was only residual impairment of hot/cold discrimination.

**Discussion:** We report the first case to our knowledge of putatively ischemic incomplete Brown-Séquard syndrome after ACDF. No evidence of surgical manipulation or other direct damage to the spinal cord was found. The probable cause therefore is a sulcal artery syndrome of unknown cause. In these circumstances, even though the prognosis is mostly favorable, further work-up in search of possible vascular pathology (dissection) and/or hypercoagulable states may be warranted.

#### P 46

##### Arterial bleeding after dorsal stabilization of the cervical spine

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**Introduction:** Today the dorsal screw and rod osteosynthesis is a common procedure for the treatment of fractures of the cervical spine. A less common, but life-threatening complication is the injury of the cervical vessels. In this case a bleeding is normally seen intraoperatively. If a haematoma is seen postoperatively, an injury of the cervical vessels has to be suspected.

**Case:** A 79-year old Patient fell and suffered a fracture of the dens axis (Anderson d'Alonso type II), which was treated in another hospital by dorsal spondylodesis C1–4. The following course was uneventful until removal of the sutures. In the further course, the patient developed a nuchal haematoma under ASS medication, so that 6 weeks postoperatively the GP sent the patient to our hospital. Clinical and ultrasound examination showed a haematoma, so that the following day an operation followed. Intraoperatively plenty of old haematoma was removed and a splashing bleeding followed in the depth which primarily could not be stopped. A tamponade was inserted and the wound was closed. An angio CT followed instantly. This revealed a transforaminal course of the left screw in the Atlas with a lesion of the vertebral artery and formation of an arteriovenous fistula. Therefore an embolization of the left Atlas-loop followed with five barricade-coils. An additional embolization of V4 from the other side was not necessary. After that the patient had to be treated in the intensive care unit for 24 days. Ventilation was required for 15 days. The revision of the wound with removal of the tamponade and secondary wound closure was uneventful. Peripheral blood flow, motor skills and sensitivity were present at all times and the further course was uneventful until discharge.

**Discussion:** This case demonstrates that if a sudden swelling appears after dorsal stabilisation of the spine even after a longer postoperative interval, it has to be thought of the possible injury of the vertebral artery. Therefore a primary angio CT is recommended.

#### P 47

##### Multimodal treatment algorithm of spine infection with intraspinal epidural involvement with and without acute spinal cord injury – analysis of diagnostics, therapy and outcome

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**Introduction:** Spinal column infections with intraspinal epidural involvement are a severe clinical picture. Spinal surgery is an important part of the multimodal treatment algorithm in the initial treatment. Intraspinal involvement is divided into spinal abscesses or empyema, which, depending on their severity, can lead to spinal cord injury (SCI). This study analyses the diagnosis, complications, outcome and treatment costs. The groups with and without SCI are compared.

**Methods:** In a monocentric study, all patients with a spinal infection and intraspinal epidural involvement were recorded in a register retrospectively since January 2012 and prospectively from May 2015 to December 2016. Antibiotic therapy of at least 6 weeks and spinal surgery were always performed. The diagnostic algorithm, outcome, complications and costs of the groups with and without SCI were analyzed descriptively. A regression analysis was performed to identify lethality factors.

**Results:** 134 patients with a mean age of  $70 \pm 12$  years were analyzed. The proportion of women was 48%. In  $\frac{1}{4}$  of all cases a spinal abscess was present. Acute SCI was present in 40% of spinal abscesses and in 45% of spinal empyema. The SCI was mainly sensorimotor incomplete (ASIA impairment scale (AIS) C and D). In primary diagnostics, the group without SCI showed significantly more cases of endocarditis (Figure 1). In 79% of the detected cases gram positive bacteria were found, followed by 12% gram negative bacteria, 7% anaerobes and 2% fungi. Patients with an acute SCI were operated on the spine significantly earlier ( $p=0.042$ ). The time from hospital admission to surgery was  $59.63 \pm 94.79$  hours compared to  $107.81 \pm 148.04$  hours in the group without SCI.

In the group with SCI the cross-sectional complications, except pneumonia, were significantly higher than in the group without SCI (Figure 1). The mortality rate was similar in both groups ( $p=0.782$ ) and ranged between 10–13%. The independent lethality factors identified were age ( $p=0.009$ ), the number of inflamed spinal segments ( $p=0.012$ ), and the Charlson comorbidity index ( $p=0.023$ ).

In patients with a SCI, ventilation time, treatment duration and subsequently treatment costs were significantly increased (Figure 2).

**Conclusion:** Spinal column infections with intraspinal epidural involvement represent a severe clinical picture with a high risk of lethality and should be operated on in spinal centres. Advanced diagnostics is recommended due to the high number of endocarditis cases and tooth involvement. Due to the higher rate of complications in acute SCI, further treatment should take place in a Centre of Spinal Cord Injuries.

Fig. 1

Diagnostik	Gruppe ohne Querschnittläsion n=79	Gruppe mit Querschnittläsion n=55	Signifikanz p-Wert
Spondylodiszitis mit Abszess, n (%)	64 (81)	42 (76)	
Spondylodiszitis mit Empyem, n (%)	15 (19)	13 (24)	0,525
Blutkulturen			
– durchgeführt, n (%)	47 (59)	33 (60)	
– davon positiv, n (%)	34 (72)	18 (55)	0,153
Echokardiographie			
– durchgeführt, n (%)	46 (58)	36 (65)	
– davon pathologisch, n (%)	9 (19)	2 (6)	0,030
Zahnstatus			
– durchgeführt, n (%)	36 (46)	20 (36)	
– davon pathologisch, n (%)	10 (28)	4 (12)	0,749
wirbelsäulenchirurgische Komplikationen	Gruppe ohne Querschnittläsion n=79	Gruppe mit Querschnittläsion n=55	Signifikanz p-Wert
Perforierende Wundsekretion, n (%)	4 (5)	3 (5)	n.s.
Fehlende Osteosynthesematerial, n (%)	3 (4)	2 (4)	n.s.
Hämatom, n (%)	2 (3)	1 (2)	n.s.
behandlungsassoziierte Komplikationen	Gruppe ohne Querschnittläsion n=79	Gruppe mit Querschnittläsion n=55	Signifikanz p-Wert
Harnwegsinfektionen, n (%)	19 (24)	24 (44)	0,024
Pneumonie, n (%)	11 (14)	11 (20)	0,356
Thromboembolien, n (%)	1 (1)	0 (0)	1,000
Dribbus, n (%)	3 (4)	9 (16)	0,027
Bildgebung: Oberfläche: MRI, n (%)			
– positiv bei Aufnahme	13 (16)	9 (16)	
– behandlungsassoziiert	3 (4)	10 (18)	0,041

Fig. 2

Behandlungszeiten	Gruppe ohne Querschnittlähmung n= 79	Gruppe mit Querschnittlähmung n= 55	Signifikanz p-Wert
Dauer Behandlung Intensivstation in Tagen	8 ± 11,01	12,88 ± 15,43	0,124
Beatmungsdauer in Stunden	136 ± 49,96	842,20 ± 237,47	0,003
Aufnahme bis Entlassung in Tage	33,41 ± 26,04	63,24 ± 44,44	0,001
Behandlungskosten	Gruppe ohne Querschnittlähmung n= 60	Gruppe mit Querschnittlähmung n= 43	Signifikanz p-Wert
Operation in €*1000, Median (IQR)	4,4 (2,6–6,4)	5,5 (3,6–8,3)	0,037
Intensivstation in €*1000, Median (IQR)	2,5 (0,9–7,2)	2,7 (0,9–8,2)	0,988
Gesamte Behandlung in €*1000, Median (IQR)	19,7 (12–27,2)	43,5 (23,1–75,1)	<0,001

## P 48

**Extremely rare case of acute paraplegia due to cavernoma in a child**\*M. Scheer<sup>1</sup>, C. Scheller<sup>1</sup>, C. Strauss<sup>1</sup><sup>1</sup>Universitätsklinikum Halle, Neurochirurgie, Halle a. d. S., Germany

**Introduction:** Cavernomas are vascular malformations that can occur in principle in all tissues. These become relevant, above all, in the central nervous system. Cavernomas account for approximately 4% of all intramedullary masses. The Conus medullaris is the rarest localization. There are only 18 case reports of cavernomas in the conus medullaris in adults. For children, there are only two case descriptions so far.

**Case Report:** A 14-year-old girl presented in the emergency room due to severe lumboschialgia. Within a few hours, a complete cross-sectional syndrome developed below the level of Th12 with bladder and bowel dysfunction. An emergency MRI showed a bleeding of 8x6 mm in the area of the conus medullaris. The emergency operative care was provided by a Laminectomy Th11. After the opening of the dura, a typical finding for a cavernoma was found. The posterior spinal artery was in the access path and could be spared. After the opening of the arachnoidea, old-blooded fluid was emptied. There was a total microscopic removal without coagulation. The histological examination confirmed the diagnosis of a cavernoma. The postoperative follow-up did not show any residual findings. The neurological status remained unchanged in the short-term. There was a timely transfer to a rehabilitation measure. In the clinical follow-up three months postoperatively, the sensitive level was slightly improved.

**Conclusion:** Cavernomas are vascular malformations that usually occur intracranially. Much less often are they intramedullary. The localization in the area of the conus medullaris is probably the rarest localization. The occurrence in children is a rarity. The onset of symptoms may be acute or slowly progressive, including motor, sensory deficits, pain and bladder / bowel disorders. Symptomatic findings should be given to surgical treatment, as the symptoms usually improve or at least do not worsen. In this case, no improvement in the neurological function could be observed in the short-term. Despite the relatively small bleeding, it came to a complete cross section. Although the surgical treatment was carried out promptly, there was no relevant improvement in the symptoms. This is very unusual as other case reports with acute onset of symptoms and timely supply report a good recovery. Also in a meta-analysis with a total of 632 patients with intramedullary cavernomas, there was clinical improvement in more than half of the cases after surgical treatment.

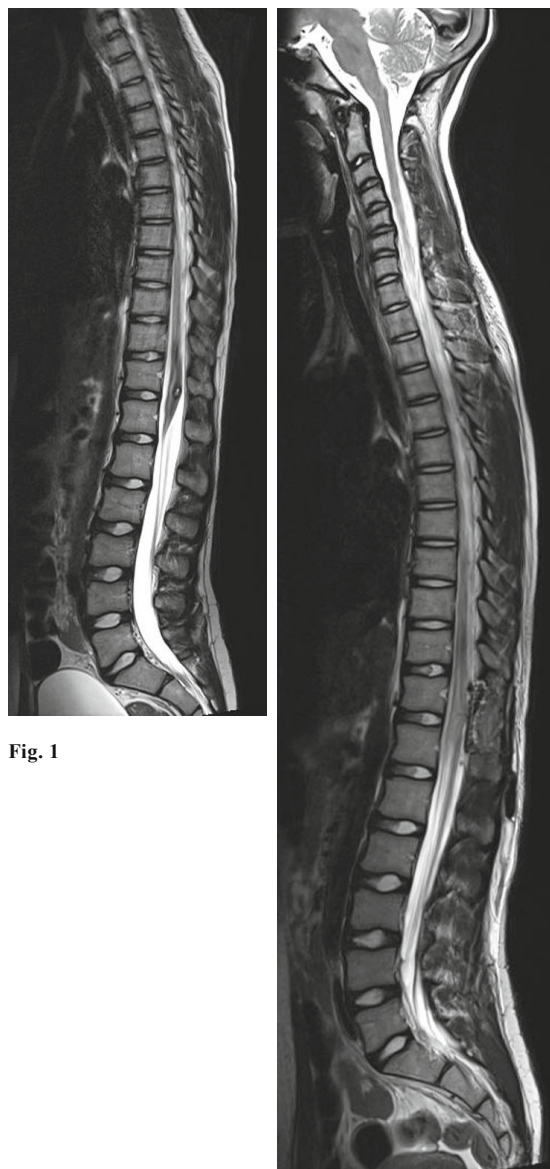


Fig. 1

Fig. 2

## P 49

**Correlation of the pedicle screw insertion torque with pedicle bone quality. Revision of the surgical technique intraoperatively: to cement or not to cement.**\*K. Kafchitsas<sup>1</sup>, P. Drees<sup>2</sup>, E. Spanidis<sup>1</sup>, M. Rauschmann<sup>3</sup><sup>1</sup>Asklepios Klinik Lindenlohe, Wirbelsäulenzentrum, Schwandorf, Germany<sup>2</sup>Universitätsmedizin Mainz, Mainz, Germany<sup>3</sup>Sana Klinikum Offenbach, Wirbelsäulenthopädie und Rekonstruktive Orthopädie, Offenbach, Germany

**Aim:** The aim of the study is the biomechanical evaluation of different pedicle screws for the spine (Biomet®, Omega 21® cannulated and Medtronic®, Solera) and the correlation of bone purchase conditions with the insertion torque of the screws.

**Material and Method:** Polyurethane blocks of different density (Cellular Rigid Polyurethane Foam-CRPF) of 7.5, 10 and 12.5 pcf (corresponding to 0.12, 0.16 and 0.20 g/cc) and polystyrene (~5 pcf) were used to measure the insertion torque. After insertion and measurement of the insertion torque, the unscrewing torque was also measured. Especially for these measurements a torque

screwdriver was developed and the corresponding adapters were manufactured. This screwdriver can also be used for intraoperative use under certain conditions and covers the amplitude of the torque values. Statistical analysis of the collected values of the variables (sigma plot) was performed.

**Results:** The maximum value of the insertion torque ( $I_{max}$ ) in the polystyrene was 0.11 Nm and the smallest ( $I_{min}$ ) 0.02 Nm (SD 0.02). In CRPF of 7.5, 10 and 12.5 pcf an  $I_{max}$  of 0.44Nm, 0.71Nm and 1.2 Nm and respectively an  $I_{min}$  of 0.06Nm, 0.08Nm and 0.14Nm was observed. The insertion and removal torque were statistical significantly ( $p < 0.05$ ) different in lower densities (polystyrene and 7.5 pcf) but not in higher densities (10 and 12.5 pcf). The insertion torques of the different densities are statistical significantly different.

**Discussion:** The cannulated screws used for this study can be cement-augmented if necessary. Based on the insertion torque, the quality of the bone and the bone purchase can be assessed and the biomechanical behaviour of the screws as well as the screw anchoring can be anticipated. For spine surgeons, the decision to augment the construct with cement can thus be made easier even intraoperatively.

## P 50

### Misaligned spinal rods can induce high internal forces consistent with those observed to cause screw pullout and disc degeneration

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**Introduction:** Mismatches between the rod and the pedicle screw heads are generally reduced during a posterior fusion operation using dedicated reduction devices. The exerted forces by these devices, however, are uncontrolled and may lead to excessive internal forces. Such forces may result in decreased screw pullout strength [1], but can also alter the biomechanical behavior of the spine postoperatively. The aim of this study is to predict such loads and deformations in the instrumentation and surrounding tissue directly after the correction is applied and during physiological flexion following successful fusion.

**Methods:** A patient-specific, lumbar spine (L1-S1) finite element model was available [2,3]. The model consists of poro-elastic intervertebral discs (IVDs) with Pfirrmann grade dependent material parameters, linear elastic bone tissue with stiffness values related to the local bone density, and the seven major ligaments per spinal motion segment described with a hypo-elastic stress-strain relationship. Titanium instrumentation was implemented in this model to represent a bi-segmental L4-S1 posterolateral fusion. Next, a misalignment of 6 mm was introduced between the rod and the screw head at L4 in the coronal and sagittal plane respectively (Fig. 1). These misalignments were computationally reduced after which a physiological flexion movement of 15° was prescribed. Non-instrumented and well-aligned instrumented models were added as control groups.

**Results:** Pulling forces up to 1.0 kN were required for correcting the induced misalignment of 6 mm. These forces affect the posture of the total lumbar spine as motion segments are shown to rotate up to segment L1-L2. In addition, both IVD and bone tissue shows to be at risk for damage as a result of the correction procedure. These regions increased during the simulation of flexion. Also for the control case without

correction, regions of high strains were found in bone and IVDs during flexion, but the total affected volume was lower than in the cases with reduction (Fig. 2).

**Discussion:** The estimated pulling forces calculated here for correcting the misalignment are expected to compromise the screw-bone interface and to induce a high risk of screw pullout. Although adverse tissue deformations are also found during flexion in the well-aligned fusion model, it should be emphasized that the deformations induced by correcting the misalignment are uninterruptedly exerted because the spine will be constrained in the enforced configuration. In conclusion, residual mismatches between spinal rod and screw head should be minimized as small deviations might result in screw loosening and tissue damage.

1. **References:** Paik et al, Spine J, 13(11):1617-26, 2013
2. Malandrino et al, Front Bioeng Biotechnol, 3:5, 2015
3. Rijsbergen et al, PLoS one, 13(8):e0200899, 2018

Fig. 1

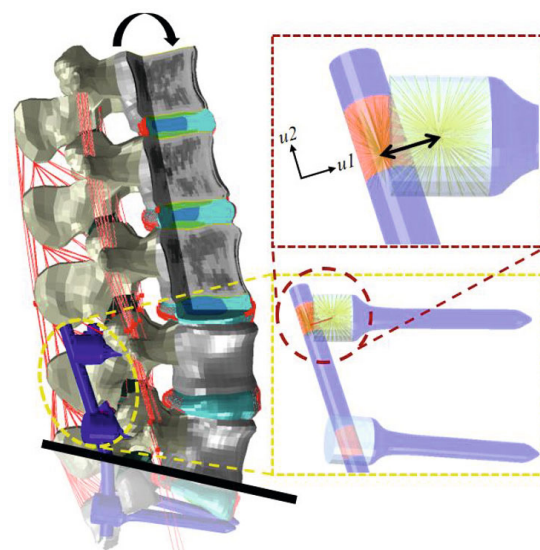
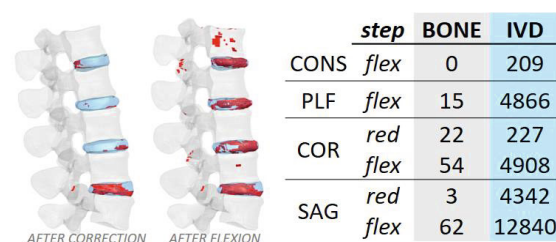


Fig. 2



## P 51

### Muscular driven spine simulator simulating flexion-extension characteristics – an experimental study

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**Introduction:** The activity of trunk muscle forces to move and stabilise the thoraco-lumbar spine has only been partially evaluated. EMG measurements of the intramuscular activity is difficult to perform as well as a validation by 3D virtual models simulating ventral and dorsal muscles. A real, experimental model may visualise muscular forces for specific trunk muscles and is able to explain pathologies of spinal disorders – and in particular the role of the iliopsoas.

The aim of the study was the acquisition of flexural characteristics of the lumbar spine by an experimental trunk muscle simulator.

**Material & Methods:** An artificial lumbar spine including 3D-printed vertebrae from S1 to L1 with homogenous, moulded silicone discs of specific shore hardness has been built. Iliopsoas and abdominal muscles were used as agonists for flexural activation, longissimus and intraspinal muscles were used as antagonists applying a constantly counteracting force. The simulator acted vice versa for extension.

Flexion/Extension were measured up to a RoM of  $+30^{\circ}/-15^{\circ}$  for a given upper body weight of 200N. Muscular loads were measured with load cells, intradiscal load with a 6 DoF sensor (Kistler AG Switzerland) in the segment L3. In order to control a semi-stable system including 5 discs with variable stiffness properties, PID controllers (National Instruments, USA) were applied force controlled [Humbert et al. 2002].

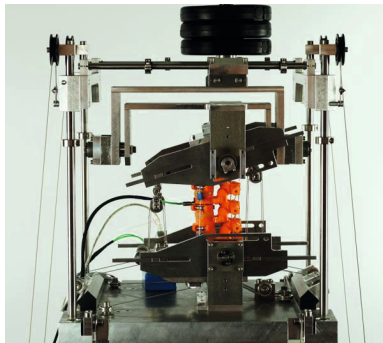
**Results:** Continuously performed flexion extension cycles were evaluated dynamically (1 full flex. or extension cycle within 10 sec). Resulting muscle force characteristics were measured and showed a maximum of about 325N – 430N for the ventral muscles (rectus abdominus) showed during flexion whereas the antagonists (dorsal muscles) counteracted in between 95N – 130N. The force for extension movement resulted in 65N -70N (ventrally) and 50N – 75N (dorsally) due to a pre-shaped intervertebral column.

**Discussion:** The simulator displayed necessary muscle forces in realtime for a substantial speed and thus having a dynamic behavior. First tests showed that flexion / extension movements of the spine were reproducibly performed for the first 3 cycles with a subsequent viscoelastic bending of the pre-shaped artificial spine. The higher forces for the flexion in comparison to extension are explained by the predefined lumbar lordosis curvature in neutral position and continuous buckling effect from the lumbar spine due to the upper body load. To optimise the reproducibility, a feedback system of the current spinal position is necessary to control the lumbar posture.

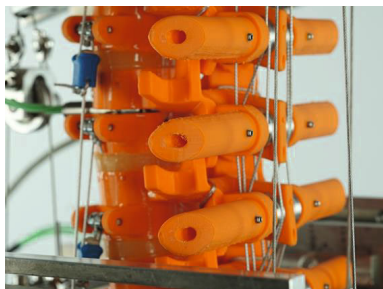
**Limitations:** the present device provides realistic muscle forces for a given external load under dynamic motion and may be used for the testing of spinal implants. The simulator needs to be extended by m. transversus and intraspinal muscles such as the m. multifidii. The upper body weight of 200 N needs to be increased to demonstrate physiology.

**References :** [1] Humbert et al., 2002

**Fig. 1**



**Fig. 2**



## P 52

### Development of a novel in vitro model of osteoporotic bone to examine new biodegradable and osteoinductive bone cement for the management of osteoporotic vertebral fractures

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**Objective:** Osteoporosis is the most common age-related progressive skeletal disease characterized by bone loss and concomitant tendency for osteoporotic vertebral fractures (OVF). The management of OVF often necessitates fusion surgery, with high rates of implant failure due to the brittle bone substance. *In vitro* models of osteoporosis to test implant pull out strength are scarce. Here we present a novel ovine model of osteoporotic bone to test an new composite osteoinductive and biodegradable bone cement to boost the anti-osteoporotic therapy and improve long term implant integrity.

**Methods:** 12 sheep vertebrae were perfused with 25% TBD-1 decalcifier solution using a double syringe pump set-up for 24h. Bone density was measured prior and after decalcification using dual-energy X-ray absorptiometry (DEXA). Osteoinductive synthetic collagen I mimetic peptide (P15) was mixed with biodegradable calcium phosphate cement (CaP). Pedicle screws were introduced into one pedicle of each vertebrae and augmented with CaP/P15. Standard polymethylmethacrylate (PMMA) cement and non-augmented screws served as control. Linear pullout testing was performed.

Osteoblastic transformation of human mesenchymal stem cells (MES) was verified via osteoblast-related gene expressions of bone-specific alkaline phosphatase2 (ALP2) and osteocalcin using Immunofluorescence and RT-PCR.

**Results:** Bone marrow density (BMD) prior to decalcification was  $0.72 \pm 0.02$  g/cm<sup>2</sup> prior and  $0.53 \pm 0.04$  g/cm<sup>2</sup> after decalcification. BMD was decreased by  $28.75 \pm 2.6$  %.

mRNA expression of ALP2 increased  $32.76 \pm 0.212$  %, while osteocalcin was increased by  $16.15 \pm 0.72$  % after co-culture of MES with CaP/P15. Immunofluorescent staining was increased in a similar manner.

Biomechanical testing in untreated vertebrae showed pullout loads of  $2010 \pm 83$  NM after augmentation with CaP/P15 compared to  $2112 \pm 49$  NM after augmentation with PMMA and  $1405 \pm 25$  without augmentation. ( $p < 0.001$ ). In decalcified vertebrae, pullout strength untreated was  $827 \pm 33$  NM and  $1250 \pm 65$  NM after augmentation with CaP/P15.

**Conclusion:** The CaP/P15 composite cement is capable of inducing osteoblastic differentiation in human MES *in vitro*. The ovine decalcification model provides a similar loss of bone marrow density as expected from osteoporotic vertebrae *in vivo* and is capable of mimicking the decreased pull out loads of pedicle screws *in vitro*. Pull out loads of CaP/P15 augmented pedicle screws are superior to controls in our model.

## P 53

### Does the intradiscal pressure really correlate with the GAG content of the disc?

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**Introduction:** Measurements of intradiscal pressure (IDP) provide important information about the loading on the spinal column and help to quantify the biomechanical quality of an intervertebral disc. However, these measurements are often assessed independently of the degree of degeneration of the examined intervertebral disc. An earlier study showed that the IDP loses its typical characteristics in more severely degenerated intervertebral discs and that the absolute pressure values decrease (Fig.1). The aim of this study was to examine whether this phenomenon can be explained by a decrease in the glycosaminoglycan (GAG) content of the lumbar intervertebral discs

and whether this correlates with the decrease in the IDP and the increase of the degree of degeneration.

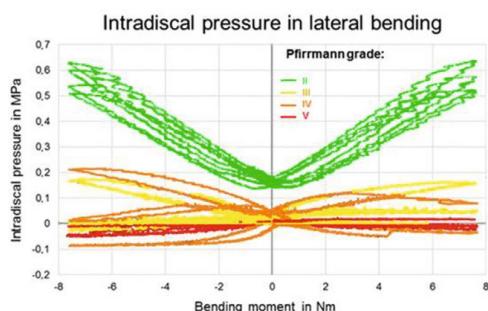
**Material and Methods** For this in vitro study, 24 human lumbar discs from 6 donors (24–68 years) with normally distributed degrees of degeneration II–V (acc. to Pfirrmann [1]) were included. From the left half of each disc, 13 cylindrical tissue samples from the nucleus, transition zone and annulus fibrosus were taken using 4 mm biopsy punches (Fig. 2a). The samples were digested with 1 mg/ml Proteinase K. The sulfated GAG content was quantified by DMMB assay and normalized to the wet weight (WW) of each sample. Statistical analyses were performed with Kruskal–Wallis test.

**Results** Surprisingly, there were no significant changes in GAG content in the entire intervertebral disc between grades II and III (in the nucleus: from 180 µg/mg to 163 µg/mg, Fig. 2a) although there was a strong difference in hydrostatic pressure in the disc (Fig. 1). With further degenerated discs (grade IV), however, the GAG content in the nucleus (104 µg/mg) and the lateral transition zone (78 µg/mg) seemed to decrease and increase in the annulus (184 µg/mg) and the medial transition zone (136 µg/mg) (Fig. 2a). In very severely degenerated intervertebral discs (grade V) the GAG content was consistently lower (Fig. 2a, 2b).

**Discussion** A true hydrostatic pressure in the intervertebral disc can only be reliably measured and correctly interpreted in a non- or slightly degenerated intervertebral disc (Fig. 1). With degeneration progress, the characteristic pressure profile of the intervertebral disc changes considerably and the measured values are no longer reliable. Overall, the loss of GAG with increase in the degree of degeneration was more consistent in the NP. Although the IDP measurements already indicate reduced hydrostatic properties in grade II of disc degeneration, the GAG content changed only slightly from grade II to III, but more significantly as degeneration progressed (grades IV and V). This phenomenon could be explained by an already decreasing water-binding capacity of the proteoglycans, which are increasingly present as proteoglycan fragments. It seems that an intact proteoglycan structure is a prerequisite for a high water-binding capacity in order to ensure hydrostatic pressure.

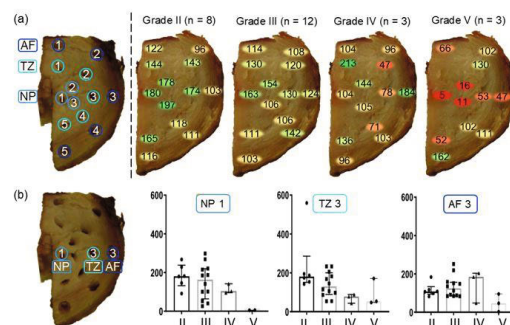
[1] *Spine* 2001; 26:1873–1878

**Fig. 1**



**Fig. 1:** Representative IDP curves in relation to the Pfirrmann degeneration grade [2], measured in a previous study. The darker the colours, the higher the degeneration grade.

**Fig. 2**



**Fig. 2:** (a) Isolated disc hemisphere with locations of the biopsy samples obtained from the different zones (NP: Nucleus pulposus, TZ: transition zone, AF: Annulus fibrosus). Heat maps of GAG content (median) of all samples depending on degeneration grade. (b) GAG of all samples in the central plane of NP, TZ and AF for the different degeneration grades.

## P 54

### Texture analysis of the vertebral bone in intraoperative CT – correlation with preoperative qCT

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**Aims:** There is a paucity of reports on whether the intraoperative CT can be used to measure bone hydroxyapatite content and microscopic spongy bone architecture. Both characteristics can affect the strength of fixation as well as long term attachment of intravertebral implants. The aim of this pilot study was to identify texture analysis parameters that possibly correlate with the hydroxyapatite content as identified on preoperative qCT and / or the occurrence of osteoporotic fractures.

**Methods:** Data from 31 patients who underwent both qCT and intraoperative AIRO CT (ioCT) were retrospectively analyzed. Regions of interest (ROIs) defined within the ioCT were placed into one vertebra either within the vertebral bodies analyzed in the qCT or into an adjacent vertebra. The freely available software package PyRadiomics was used to perform the texture analysis after applying the wavelet filter to the source ioCT image. Apart from the first order parameters based on pure density measures, parameters that correlated the most with the hydroxyapatite levels measured by qCT and or the occurrence of previous osteoporotic fractures were further analyzed.

**Results:** Predictably, there was a strong correlation of the mean ROI density with the hydroxyapatite content ( $r=0.843$ ,  $p<0.01$ ). Among the texture features, the "Contrast" parameter of the Gray-Level Co-occurrence matrix group showed the largest correlation with the hydroxyapatite content measured by the previous qCT ( $r=-0.562$ ,  $p=0.001$ ; this parameter is a measure of the local intensity variation, a larger value correlates with a greater disparity in intensity values among neighboring voxels). The Mann-Whitney U test showed a significant difference between the feature "Large Dependence High Gray Level Emphasis" and the history of osteoporotic fractures of the spine ( $p=0.011$ ). This feature expresses the presence of high intensity clusters in the ROI.

**Conclusions:** Texture analysis might provide insight into the structural changes of the bone tissue based on bone images from intraoperative CT. Further analyses are needed in order to determine whether this information can be used for intraoperative decision making regarding, for instance, larger diameter screws or cement augmentation.

## P 55

### How much does the intradiscal pressure differ between cervical, thoracic, and lumbar spine? – a meta-analysis

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**Introduction:** Data on human intradiscal pressure is essential for the estimation of spinal loads and muscle forces, but also for the validation of numerical models and experimental setups. The purpose of this meta-analysis therefore was to summarize all in vitro measurements of human intradiscal pressure performed under defined boundary conditions in order to detect potential relationships between the hydrostatic pressure in the human intervertebral disc and both the segmental level and the loading direction.

**Material/Method:** Systematic review of the literature was conducted to extract all intradiscal pressure values measured without external loading (intrinsic pressure), under axial loading (compression, traction, shear), and under single-planar bending loading (flexion, extension, lateral bending, axial rotation) from previous in vitro studies on cervical, thoracic, and lumbar human specimens. Data was evaluated regarding the segmental level and normalized to force and moment. Regression analysis was performed to investigate coefficients of determination and statistical significance of relationships between intradiscal pressure and segmental level for the single loading conditions.

**Results:** 35 studies were detected fulfilling the inclusion criteria (10 for the cervical, 3 for the thoracic, and 22 for the lumbar spine), from which a total of 451 data points were collected for the meta-analysis. High coefficients of determination were found in axial compression ( $r^2 = 0.875$ , Fig. 1) and flexion ( $r^2 = 0.781$ ), while being low for intrinsic pressure ( $r^2 = 0.266$ ) and lateral bending ( $r^2 = 0.385$ ), all showing significant regression fitting ( $p < 0.01$ ). The intradiscal pressure generally decreased from the upper cervical spine to the sacrum in all loading conditions, being approximately 5–10 times higher in the upper cervical (1–3 bar/Nm) compared to the lower lumbar spine (0.1–0.3 bar/Nm) under bending load, while the intrinsic pressure exhibited a minimum of the regression curve in the mid-thoracic spine.

**Discussion:** Despite potential limitations regarding the comparability of the selected data, clear indications were found that the human intradiscal pressure represents a function of the segmental level and the loading direction. This can be explained by the size differences of the intervertebral discs, comparable with the pressure differences in truck, car, and bike tires. Moreover, the present study provides a large data set for the estimation of spinal loads and the validation of numerical models and experimental setups. These data can be used as guide values in order to interpret the validity of future intradiscal pressure measurements and promote the understanding of the load distribution along the entire spine.

**Fig. 1**

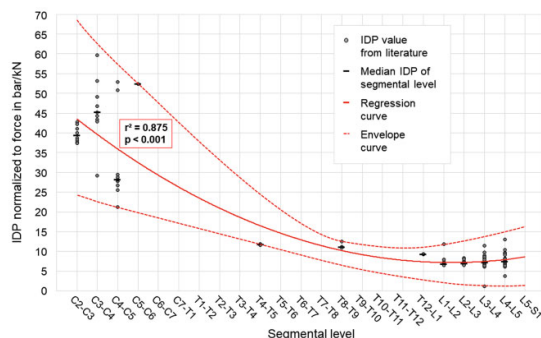


Fig. 1: Intradiscal pressure (IDP) values in axial compression as a function of the segmental level.

## P 56

### Biomechanical evaluation of patient guided CBT vs MC vs cement augmented pedicle screws

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**Background:** In stabilizations of the lumbar spine, pedicle screw placement is the most common technique. The Cortical bone trajectory (CBT) – placement is an alternative technique in terms of both fixation strength and less invasiveness. To insert the screw with penetrating cortical bone on the ideal trajectory is technically demanding. The use of three-dimensional patient-specific drill template (PSDT) facilitates the use of this technique. Regarding to the literature the "long CBT" or Midline cortical (MC) seems to be superior to the classic CBT and comparable to pedicle screws. The purpose was to compare the anchorage of the screws using patient guided CBT and MC vs freehand cement augmented traditional trajectory (CATT) pedicle screw due to a biomechanical analysis in order to evaluate whether the CBT or the MC is a possible alternative to CATT.

**Methods:** Ten human cadaveric specimens (L1 to L5) were dissected, mean age was  $87.7 \pm 6.7$  years. Preoperative CT-scans of the specimens were made for the surgical planning and the PSDT for implantation of the CBT and MC were produced. The specimens were divided into two groups for static and dynamic

examination. Before the tests, the vertebral bodies were embedded using polyurethane casting resin

In group A, CBT and MC were implanted randomly. In group B, MC was compared to CATT. Both groups (A and B) were divided into subgroups. One group for the static tests (group 1) with L2 and L4 and the second one for the dynamic tests (group 2) with L1 and L3.

**Results:** In group A 5 all five vertebral bodies were successfully tested and in group B five L1, five L2, four L3, four L4 and four L5 vertebral bodies. In group A1, 18 of 20 screws were successfully pulled out. MC screw data were obtained from five L2 vertebral bodies and three L4 vertebral bodies, whereas all CBT screws were tested successfully. In group B1, 16 of 18 screws were successfully pulled out. MC screw data were obtained from five L2 and four L4 vertebral bodies. The CATT was gained from four L2 vertebral bodies and three L4 vertebral bodies. Group A1 showed a mean pull-out force of  $553.4 \pm 226.3$  N for the CBT and  $599.1 \pm 342.7$  N for the MC screws. For group B1 a higher pull out force of  $990.3 \pm 284.2$  N was determined for CATT compared to  $691.0 \pm 398.0$  N for MC. Vertebral body L2 showed a higher difference between MC ( $599.7 \pm 427.7$  N) and CATT ( $994.2 \pm 342.1$  N). In the dynamic test in group A2 one MC screw had loosened before reaching the 10000 cycles and 5 CBT screws had loosened before test end. In the group B2, no signs of failure or loosening were observed in CATT. Regarding MC, loosening occurred in three screws before reaching the 10,000 cycles, after 26 cycles, 1,500 cycles, and 2,200 cycles, respectively.

**Conclusions:** Regarding to out tests, CATT showed the highest pull out forces, followed by MC and CBT. The gold standard regarding the pull out forces remain CATT, but the MC represents a sufficient alternative in the osteoporotic patient.

## P 57

### The locations of the Instantaneous Helical Axis of the functional spinal unit T4-5 during axial rotation

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**Introduction:** Research on the biomechanical characteristics of the thoracic spine and particularly on the location, direction, and migration of the Instantaneous Helical Axis (IHA) is rare. While the location of the IHA has been studied, the results are contradictory. Furthermore, the impact of the facet joints on the location of the IHA remains to be elucidated. The aim of this study was to examine the kinematics of the functional spinal unit T4-5 during axial rotation in intact conditions and after bilateral facetectomy.

**Material & Methods:** An established 6D-measuring apparatus was used to examine four human functional spinal units T4-5 ( $69.0 \pm 19.1$  years, 2 female) during axial rotation in intact conditions and after bilateral facetectomy. Examination of the specimens was performed after soft and muscular tissues, ribs, vessels, and neural structures were removed. Ligaments and joint capsules were left intact. The weight of the head and the upper thorax were simulated by preloads. The direction, position, and migration of the IHA in the axial plane in relation to the vertebrae were calculated. Results are presented for the range of axial rotation between  $-1^\circ$  and  $+1^\circ$ . A modified direct approach to the determination of the IHA was used.

**Results:** Under intact conditions, the IHA migrated about  $4.4 \pm 2.9$  mm and was always located in the anterior part of the spinal canal. After bilateral facetectomy, the migration was less than in intact conditions, but did not differ significantly. The location of the IHA shifted anteriorly about 10 mm compared to the IHA in intact conditions ( $p = 0.028$ ). In general, the migration of the IHA was a movement from dorsal to ventral rather than a movement from one side to the other. In intact conditions, the direction of the IHA was minimally dorsally reclined under all preloads and with axial

rotation to both sides. After bilateral facetectomy, the IHAWs significantly more ventrally inclined.

**Discussion:** The study determined the location of the IHA under intact conditions at the anterior part of the spinal canal. The IHA is substantially influenced by the guidance of the facet joints. The facet joints and their capsules seem to have an impact on sagittal stability. The anterior shift of the IHA and the alterations of the direction of IHA after bilateral facetectomy indicate a distinct alteration of the kinematics of the functional spinal unit T4-5.

#### Figure 1: Shift of the location of the IHA after bilateral facetectomy

The direction and the migration of the Instantaneous Helical Axis (IHA) in relation to T5 in intact conditions (A) and after bilateral facetectomy (B) is depicted. Visualization of IHA for axial rotation between  $-1^\circ$  to  $+1^\circ$  degree. Colors define different preloads: Central preload: grey; Dorsal preload: green; Ventral preload: red; Right preload: yellow; Left preload: blue.

Fig. 1

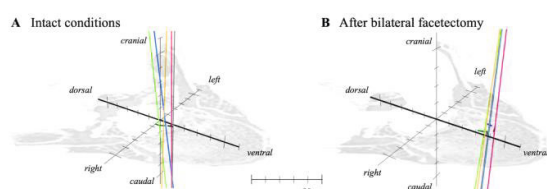
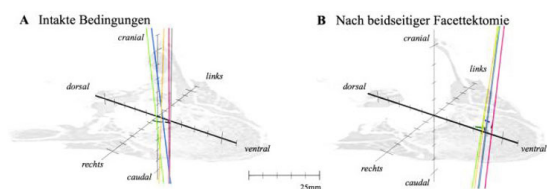


Fig. 2



#### P 58

##### Isthmic lumbosacral spondylolisthesis: radiographic and patient reported outcomes after anterior lumbar interbody fusion

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**Introduction:** The optimal surgical management of isthmic spondylolisthesis is controversial and reports on anterior approach for low-grade isthmic spondylolisthesis in the literature are scarce. We present the radiographic and patient reported outcomes after anterior lumbar interbody fusion in patients with symptomatic L5-S1 isthmic spondylolisthesis.

**Materials/Methods:** All adult patients with documented L5-S1 isthmic spondylolisthesis treated between 2008 and 2019 with ALIF were screened. All surgeries were performed by an experienced spine surgeon, through a retroperitoneal approach, a titan cage was inserted at L5-S1 with anchoring screws in the endplates. Prospectively collected clinical and surgical data as well as radiographic parameters were analyzed retrospectively. All patients were asked to complete the Oswestry Disability Index (ODI) and Core Outcome Measures Index (COMI) before and after surgery.

**Results:** In total, 34 patients (19 men, 15 women) with a mean age of 52.5 ( $\pm 11.5$ ) years were included for final analysis. The mean maximal follow-up (FU) was 2.7 ( $\pm 2.4$ ) years, the mean ASA risk classification was 2.0 ( $\pm 0.6$ ). The mean pelvic incidence was 64.9 ( $\pm 8.7$ )°. 73.5% (n=25) of patients had a spondylolisthesis grade I, 23.5% (n=8) grade II and 2.9% (n=1) grade III according to Meyerding classification. Mean lumbar lordosis increased from 58.9 ( $\pm 9.4$ )° before surgery to 64.5

( $\pm 9.2$ )° after surgery. Mean COMI and ODI scores improved from 6.9 ( $\pm 1.5$ ) and 35.5 ( $\pm 13.0$ ) to 2.0 ( $\pm 2.5$ ) and 10.2 ( $\pm 13.0$ ), respectively after one year, and to 1.7 ( $\pm 2.5$ ) and 8.2 ( $\pm 9.6$ ), respectively after two years. The COMI score improved in 86.4% of patients after one year and 92.9% of patients after two years by at least the minimal clinically important change (MCIC) score of 2.2 points. Preoperatively, mean VAS values for back and leg pain measured 5.3 ( $\pm 2.5$ ) and 6.8 ( $\pm 2.3$ ), respectively, and improved to 1.9 ( $\pm 1.8$ ) and 1.7 ( $\pm 2.5$ ), respectively at one year FU (22/34 patients), and to 1.6 ( $\pm 2.3$ ) and 1.2 ( $\pm 1.5$ ), respectively at two years FU (14/34 patients). There were no records of intraoperative vascular or other major complications. The reoperation rate was 8.8% (n=3) in the observation period.

**Discussion:** Patient reported outcomes after ALIF for symptomatic isthmic spondylolisthesis showed clinically important improvement after one and two years. These results suggest that with good patient selection and necessary surgical experience, the ALIF is an effective and save surgical treatment option for low-grade isthmic spondylolisthesis.

#### P 59

##### Lumbar lordosis after monolevel minimally invasive spondylodesis: Measurements by different raters lead to different results – a statistical challenge

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**Introduction:** The constellation of spinopelvic parameters is of increasing interest in spinal surgery. The common manual measurement of those angles using single X-rays in principle is susceptible to rater-dependent variability, which has not been adequately considered in previous studies. Therefore, this study investigates the effect of rater-dependent measurement differences of the lumbar lordosis angle in pre- and postoperative characterization of patients with lumbar spondylolisthesis.

**Methods:** The lumbar lordosis angle on pre- and postoperative standing X-rays in 43 prospectively included patients undergoing minimally invasive, monolevel TLIF were evaluated by 4 raters (A-D). Subsequently, the Intraclass Correlation Coefficient (ICC) was calculated for each pair of raters as well as for all together to evaluate the interrater reliability. The Wilcoxon test was used to compare the pre- to postoperative change in the lordosis angle in every patient for each rater separately.

**Results:** The ICCs were "good" ( $>0.75$ ) for 1 rater pair and "excellent" ( $>0.9$ ) for the other 5 individual pairings and all raters together (Fig.1). The comparison of the lumbar lordosis angles pre- and postoperatively showed a significant increase of  $+2.5^\circ$  (A) and  $+3.8^\circ$  (C) in 2 raters, and no significant difference for the other ones (B:  $+2.1^\circ$ ; D:  $-2.2^\circ$ ; Tab.1).

**Discussion:** The pre- to postoperative changes in lumbar lordosis revealed different levels of significance for different raters, although the ICCs were formally mostly excellent between all raters (Fig.1). Accordingly, the evaluation by only 1 rater would lead to different conclusions: Rater A and C would postulate a significant increase in lumbar lordosis following minimally invasive TLIF, while rater B and D would not detect any significant change.

We conclude, that due to the susceptibility of spinopelvic parameter measurements to rater-dependent variabilities, several actions are recommended to increase reliability when evaluating significant changes: First, the measurements should be performed by several raters and the agreement should be statistically determined by ICC calculation. Second, even if the reproducibility is formally excellent, a validation of the consistency of the results in each rater should be included. In case of inconsistent levels of significance, the results should be handled with caution.

**Figure 1:** Calculation of ICCs (95%-CI) of the individual rater pairs (permanent line) and all raters together (dashed line). ICC $>0.9$  is considered as "excellent",  $>0.75$  as "good" agreement.

**Table 1:** Overview of pre- and postoperative lordosis angles of all 43 patients as median (inter-quartile-range). Ratets A and C revealed a statistically significant increase of the lordosis angle (p $<0.05$ ), whereas B and D showed no significant difference.

Fig. 1

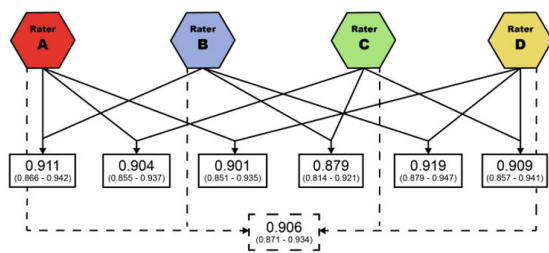


Fig. 2

Rater	Lumbar lordosis angle			
	preoperative	$\Delta$	postoperative	p-value
<b>A</b>	57.0° (50.0 - 64.0)	+2.5°	59.5° (52.0 - 68.0)	<b>0.014*</b>
<b>B</b>	57.0° (50.2 - 67.7)	+2.1°	59.1° (51.9 - 68.1)	0.171
<b>C</b>	53.8° (47.4 - 64.8)	+3.8°	57.5° (48.7 - 67.9)	<b>0.015*</b>
<b>D</b>	59.3° (50.2 - 66.0)	-2.2°	57.1° (50.9 - 66.7)	0.522

## P 60

### Metrics development for minimalinvasive unilateral Laminotomy for Bilateral Decompression (ULBD) of lumbar spinal stenosis with and without Spondylolisthesis

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**Background:** Surgical training, on both trainee and master levels, intends to enable a surgeon to acquire the theoretical and practical knowledge necessary to perform a designated surgical procedure skillfully, reliably, and safely.

**Purpose:** To develop, operationally define, and seek consensus from procedure experts on the metrics that best characterize a reference approach to the performance of a minimally invasive unilateral laminotomy for bilateral decompression (ULBD) for lumbar spinal stenosis.

**Methods:** A Metrics Group consisting of three experienced spine surgeons (two neurosurgeons, one orthopedic surgeon), each with over 25 years of clinical practice, and an educational expert formed the Metrics Group that characterized a lumbar decompression surgery for spinal stenosis as a "reference" procedure. In a modified delphi panel 26 spine surgeons from 14 countries critiqued these metrics and their operational definitions before reaching consensus.

**Results:** Performance metrics consisting of 6 Phases with 42 Steps, 21 errors, and 17 Sentinel errors were identified that characterize the procedure. During the peer review, these were evaluated, modified, and agreed.

**Conclusions:** Surgical procedures can be broken down into elemental tasks necessary for the safe and effective completion of a reference approach to a specified surgical procedure. Spinal experts from 16 countries reached consensus on performance metrics for the procedure. This metric-based characterization can be used in a training curriculum and also for assessment of training and performance in clinical practice.

Fig. 1

Complete ipsilateral decompression				Time taken:
Start	Ipsilateral medial flavum has been removed	Step	Error	Start time:
22	Study prep MRI in sagittal and/or axial view in order to determine how far caudally the decompression has to be extended.			
23	Extend decompression toward ipsilateral (if using a tube adequate wand of the tube is necessary)			
24	Thin out bone with drill and remove with 45° or 90° Kerrison until the lateral edge of the dura is identified (Avoid injury to pars inf.)			
25	Work caudally to at least half of the ipsilateral L5 pedicle (check sagittal MRI). Remove a few mm bone of the upper part of L5			
26	Identify the medial wall of the ipsilateral L5 pedicle with the ball tip			
27	Identify the lateral edge of the dural sac to confirm opening of lateral recess			
28	Inspect disc by medializing dura with ball tip or dissector and determine if discectomy should be performed			
End	Lateral recess is opened			Finish time:

## P 61

### The Influence of Shape and Position of Cages on Segmental Stabilization and Bone Loading in Transforaminal Lumbar Interbody Fusion – a Finite Element Perspective

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**Introduction:** Clinical outcome of transforaminal lumbar interbody fusion (TLIF) is dependent on segmental stabilization as well as sagittal alignment and disc height restoration, which are directly related to cage subsidence. TLIF cages are available as straight devices placed in oblique fashion and banana-shaped devices to be placed medially in more or less anterior positions. It is the goal of this study to better understand the effect of the respective cage type and positioning on bone loading and cage subsidence.

**Method:** A nonlinear finite element (FE) model of a lumbar spine with reduced bone strength was developed and validated by comparing its range of motion with literature data. TLIF cages and the corresponding facetectomy, discectomy and posterior pedicle screw instrumentation were modeled in segment L4-L5. The implanted cages were a straight oblique cage (obl) and a banana shaped cage with positions ranging from central to anterior (cnt, ½ant and ant) (Figure 1, A-D). Both cage types were given identical endplate contact surface area. The spine was subjected to a follower load (FL) of 400 N and a flexion of 7.5 Nm, which is the expected maximum loading condition. We then reviewed the correlation between the results of our FE model and outcomes of retrospective studies comparing TLIF with straight oblique and banana cages.

**Results:** With 0.42 mm, sinking into the superior L5 endplate was highest for the straight oblique device, while for the banana shaped device it decreased further with more anterior cage positions, the maximum value being 0.15 mm (Figure 1, E to H). For the straight device, plastic deformation of bone occurred below the endplates and in the vicinity of the pedicle screws (Figure 1 I), an indicator for risk of subsidence and screw loosening. For the banana shaped device, the volume of plastically deformed bone was smaller and it decreased further with more anterior cage positions (Figure 1, J to N). An improved segmental stabilization was also noted for the banana device (Figure 1 O).

**Discussion:** Various retrospective studies compared the outcome of TLIF procedures with straight oblique and banana cages. It was found that restored disc height and segmental lordosis were significantly higher in the banana cage group than in the straight cage group (Figure 2). Sagittal alignment and disc height following TLIF are intimately connected to cage subsidence. A higher loading of the bone surrounding intervertebral cages increases the risk for cage subsidence. Our FE model has shown the banana cage to generate less bone loading than the straight oblique cage under combined FL and flexion. This may explain the superior ability of banana cages to restore and maintain sagittal alignment and disc height over time compared to straight oblique cages observed in various studies.

Fig. 1

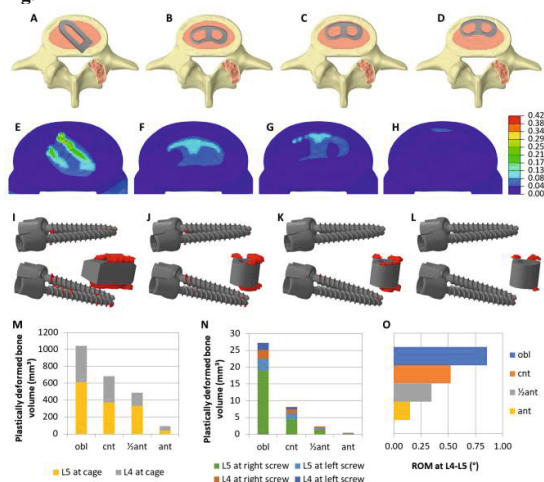
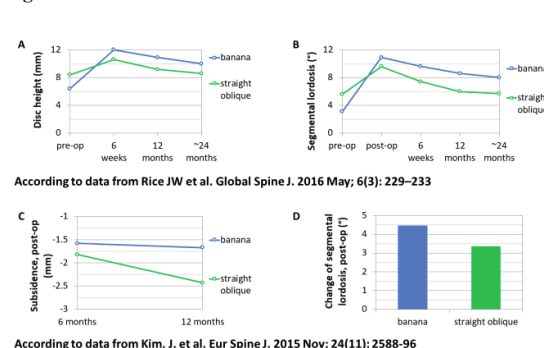


Fig. 2



## P 62

## Pelvic incidence is associated with lumbar muscle atrophy but not with severity of stenosis in patients with degenerative lumbar spinal stenosis

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**Objective:** Sagittal balance and trunk muscle atrophy are important factors in patients with lumbar spinal stenosis that may affect patients' quality of life or risk of falls [1]. Pelvic incidence (PI) is greater in older persons [2] and may be associated with lumbar muscle atrophy (LMA) and lumbar spinal stenosis (LSS). The objective of this study was to determine if PI is associated with LMA stage or LSS severity.

**Methods:** We retrospectively included all patients with degenerative LSS who had received surgery at our clinic in 2018 and 2019. Demographic information was extracted from patient files. LMA stage was classified according to Goutallier [3]. From magnetic resonance images (MRI) of the lumbar region, LSS severity was graded according to Schizas [4]. Both parameters were assessed at L1-2, L2-3, L3-4, L4-5, and L5-S1 segments. Overall LMA was computed as average LMA stage of all segments because atrophy at each segment was assumed to affect overall

muscle function. Overall LSS severity was defined as the highest LSS severity at all segments. The sagittal spinopelvic parameter PI was measured from upright standing sagittal plane X-ray of the lumbar spine [5]. Associations among parameters were assessed using Spearman correlation coefficients adjusted for age ( $??=0.05$ ).

**Results:** A total of 194 patients (93 males; mean (range) age: 67.7 (42–86) years) were included. The mean of the average LMA stage was 1.4 (0–4), and the PI was 57.1° (35–79°). LSS severity was grade 1 in 11 patients, grade 2 in 57 patients, grade 3 in 100 patients, and grade 4 in 27 patients. All parameters correlated significantly with age ( $R>0.410$ ;  $P<0.001$ ). PI correlated significantly with average LMA stage before ( $R=0.452$ ,  $P<0.001$ ; Figure 1) and after adjusting for age ( $R=0.252$ ,  $P<0.001$ ). PI did not correlate significantly with LSS severity before ( $R=0.125$ ,  $P=0.082$ ) or after adjusting for age ( $R=-0.067$ ;  $P=0.335$ ). Average LMA stage correlated significantly with LSS severity before ( $R=0.252$ ,  $P<0.001$ ) but not after adjusting for age ( $R=0.093$ ;  $P=0.201$ ).

**Conclusions:** Clinically, LSS symptoms frequently do not agree with imaging based LSS severity [6]. The lacking association between PI and LSS severity and between LMA and LSS severity suggests that LMA may play an important but independent role in the clinical manifestation of LSS. These results emphasize the importance of routinely assessing LMA and symptoms in patients with LSS to further elucidate the etiology of this disease.

**References:** 1 Ito et al. *Geriatrics*. 2019;4(2):38

2 Bao et al. *Eur Spine J*. 2018;27(2):482–488

3 Goutallier et al. *Clin Orthop Relat Res*. 1994;304:78–83

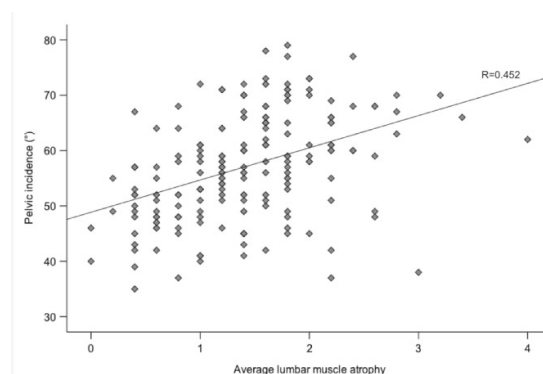
4 Schizas et al. *Spine*. 2010;35(21):1919–1924

5 Celestre et al. *Neurosurg. Clin. N. Am.* 2018;29(3):323–329

6 Vagaska et al. *Medicine* 2019;98(17):e15377

**Figure 1.** Association between pelvic incidence and lumbar muscle atrophy.

Fig. 1



## P 63

## Influence of cage design on clinical and radiological outcome in dorsal lumbar spondylolysis – a comparison of lordotic and non-lordotic cages

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**Background:** The implantation of a cage is mandatory for many spine surgeons in dorsal spondylolysis. In this context, the choice of the right cage design plays an important role. Among others, non-lordotic (rectangular) and lordotic (wedge-shaped) cages are available. Modern cages can influence the sagittal profile due to their geometry. Previous studies showed improved lumbar lordosis in lordotic cages compared to non-lordotic cages (1). However, it is largely unknown whether the radiological outcome is also reflected in the clinical scores, especially in the long-term follow-up. Therefore we first asked whether we can confirm the improvement in lumbar lordosis described in the literature in our patient population.

Furthermore we wanted to investigate, if the radiological improvement leads to changes clinical follow-up.

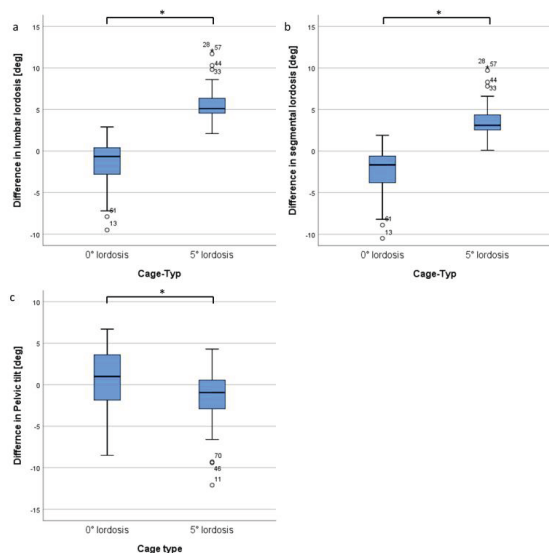
**Methods:** Therefore we compared in a retrospective study design 37 patients with non-lordotic cage (NL-group) and 40 with a 5°-lordotic cage (L-group) implanted mono- or bisegmental in TLIF-technique and analyzed radiological parameters pre- and postoperative (Lumbar lordosis (LL) and segmental lordosis (SL), pelvic tilt (PT) as well as clinical parameters in a follow up physical examination minimum two years postoperative (Oswestry disability index (ODI), Roland-Morris Disability Questionnaire (RMQ) and visual analog scale (VAS))

**Results:** As expected, we found significantly better results in radiological outcome in the L-group compared to the NL-group (fig. 1). LL decreased 1° in NL-group (50° preoperative to 49° postoperative) and increased 6° in L-group (51° to 57°) ( $p<0.001$ ). No difference in SL in NL-group (15°) and increase of 5° in L-group (13° to 18°) ( $p<0.001$ ). Also no difference in PT in NL-group (20°) and decrease of 2° in L-group (21° to 19°) ( $p=0.008$ ). In contrast, the clinical outcome showed no significant difference between the two groups. ODI in NL-group was 23% vs. 28% in L-group ( $p=0.25$ ), RMQ in NL-group was 8 points vs. 9 points in L-group ( $p=0.48$ ) and VAS was in NL-group 2.7 vs. 3.2 in L-group ( $p=0.27$ ) (fig. 2). Regarding the multivariate analysis, the results show a significant multivariate influence across all variables of BMI (Wilks  $\lambda = 0.57$ ,  $F(4, 44) = 3.61$ ,  $p = .012$ ) and preoperative SS (Wilks  $\lambda = 0.66$ ,  $F(4, 44) = 2.54$ ,  $p = .05$ ). Gender, age, cage type and postoperative PT had no significant influence ( $p>0.05$ ). Patient related parameters like BMI and preoperative SS had significant influence on ODI and RMS.

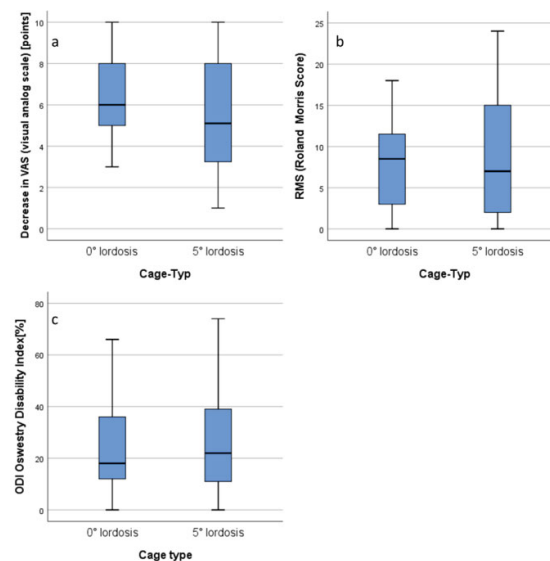
**Discussion:** In conclusion, we think that other influenceable factors such as correct indication and adequate decompression make up the main part of the success and the minimal difference in the lumbar lordosis is therefore of subordinate importance.

1. Sembrano et al.; Do Lordotic Cages Provide Better Segmental Lordosis Versus Nonlordotic Cages in Lateral Lumbar Interbody Fusion (LLIF)? Clin Spine Surg. 2017

**Fig. 1**



**Fig. 2**



## P 64

### Impact of the positioning on the intraoperative blood loss and reconstruction of the segmental lordosis after dorsal lumbar interbody fusion

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**Introduction:** The dorsal lumbar interbody fusion is an established surgical procedure for the treatment of degenerative spinal diseases. The operation is typically performed in prone position, but within the last decades different possibilities of positioning has been developed. While the knee-elbow position reduces the abdominal pressure but deflects the lumbar spine, the prone position leads to more lumbar lordosis and therefore enables an easier reconstruction of the lumbar spine. The aim of this study was to analyze whether the type of positioning influences the intraoperative blood loss as well as the reconstruction of the segmental lordosis. We hypothesized, that patients operated in knee-elbow position had less intraoperative blood loss, but in addition less correction of the segmental lordosis.

**Methods:** This monocentric retrospective study included patients who received a dorsal lumbar interbody fusion between January 2014 and December 2018. Inclusion criteria were mono- and bisegmental fusions of the lumbar spine due to degenerative lumbar diseases. Patients were positioned in knee-elbow position (group I) or prone position (group II). Exclusion criteria were vertebral fractures, infectious and tumor-related diseases. Demographic and perioperative data as well as the intraoperative blood loss were collected. Two examiners each independently measured the pre- and postoperative segmental lordosis at two different times.

**Results:** 130 patients (46.9% female) with an average age of 66.4 years ( $\pm 10.9$ ) were included in the study. Group I consists of 110 patients, group II of 20 patients. The average body mass index was 30.4 ( $\pm 6.7$ ). The blood loss did not significantly differ between group I (600.0ml  $\pm 248.0$ ) and group II (684.5ml  $\pm 242.8$ ,  $p = 0.204$ ). Both groups showed a significant increase of segmental lordosis pre- to postoperatively (group I:  $-6.0^\circ$   $7.2^\circ$ ,  $p < 0.01$ , group II:  $-5.1^\circ$   $8.8^\circ$ ,  $p = 0.02$ ) without significant difference in curve correction in direct group comparison ( $p = 0.967$ ). The inter- and intraclass reliability was between 0.887 and 0.956.

**Discussion:** Both, the knee-elbow and the prone position allow an adequate reconstruction of the segmental lumbar lordosis. According to the results of our study, the knee-elbow position is

not superior to prone position with respect to the intraoperative blood loss.

#### P 65

##### **The dynamic instrumentation of the lumbar spine shows no protective role in regard to adjacent segmental disease – 5 years appraisal of a peek rod based dynamic instrumentation construct.**

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**Background:** Adjacent segment disease (ASD) is a well known consequence of fusion surgery in the lumbar spine, reaching up to 50% at 5 years. To this avail many dynamic instrumentation systems have come about but only little information regarding their effectiveness in preventing ASD is known.

**Purpose:** The present retrospective study aimed at delivering first results after the use of a novel pedicle based, screw and peek rod system. Emphasis was placed on the ability of the construct to prevent adjacent segment disease at an average of 5 years follow up by maintaining a certain degree of movement in the index segment. This was evaluated via functional X Rays before and after surgery in accordance with the concept proposed by Dvorak almost 2 decades ago.

**Methods:** The cohort was made up of 33 patients which received decompressive surgery in one segment followed by dynamic instrumentation with a dynamic screw and peek rod based construct for stenosis of the lumbar spinal canal and degenerative spondylolisthesis. We analyzed diagnostic imagery including functional X Rays of the above mentioned patients prior and after surgery as well as cohort related demographics such as reoperation rate, complications, rate of screw loosening and overall patient satisfaction with the result.

**Results:** The ages ranged between 39 and 82 years with an average of 67. At an average of 68,7 months follow up there were 23 cases of radiological adjacent segment disease. We defined a radiological ASD as an increase of the osteoarthritis on the Wiener scale and stenosis of the spinal canal on the MRI scans. Screw loosening were verified in CT and documented. Out of the 33 patients, 17 retained an improvement of symptoms at the mean follow up with the others either requiring renewed surgery in the index segment or having developed clinically significant ASD.

**Conclusions:** The construct being evaluated showed no preventive role in ASD cranially and under the clinical point of view no marked benefit when compared against decompressive surgery and fusion.

#### P 66

##### **Drainage management for open thoracolumbar spinal fusion surgery – a Germany-wide survey**

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**Introduction:** Wound drains after open spinal surgery are inserted regularly, although the evidence is unclear and the topic is handled very differently. Approved standards or official recommendations are lacking. The aim of the survey was to assess the current use of wound drainages after open spinal surgery in Germany.

**Material & Methods:** Online survey (UmfrageOnline, enuvo GmbH, Switzerland) among all members of the German Spine Society (DWG) and the Spine Section of the German Society for Orthopaedics and Trauma (DGOU) over a period of 2 weeks. In addition to the opinion survey of the preferred drainage management, information about the participants (specialty, position, experience) were also collected. Furthermore, the subjective opinions on the possible effects of wound drainages were inquired.

**Results:** The survey was sent to 2400 participants of which 441 (18.4%) responded. Surgeons from private practices and all sizes and types of clinics participated. Almost 30% of participants were either senior physicians or deputies or chief physicians, respectively. The overwhelming majority (74.9%) (almost) always inserts a drainage. In 98.7% of cases, a subfascial drainage is placed. One (49.9%) or several (47.2%) drains are almost equally placed, whereas drains with suction (64.9%) are predominant. The decision whether to place drainages is heterogeneous. In the vast majority of cases, the drain is removed on the first (40.4%) or second (63.0%) day. The most often chosen criterion for a removal by flow rate was less than 50ml in 24 hours (34.6%). In case of a dural tear negative pressure drainage is mostly avoided (64.8%) or the drainage management depends on the type of tear repair. Microbiological examination of drain tips is never (65.5%) or performed if infection is suspected only (27.9%). The statement "Drainages prevent haematomas" is answered by 81.6% with *true* or *rather true*. The questions "Drainages reduce neurological deficits", "Drainages increase the rate of wound infection", "Drainages cause higher blood loss", and "Drainages increase the probability of postoperative blood products" were answered with either *not true* or *rather not true* in 73.4%, 73.4%, 72.9%, and 85.9% respectively. The answer to the question "Drains reduce wound healing disorders" was inconsistent.

**Discussion:** With 441 participants, this is the largest data collection in the German-speaking countries to date. Placement of a drainage in open thoracolumbar fusion surgery is the standard procedure for 74.9% of the participants, with subfascial drainages being the type most often used. Drainage management is inconsistent, but 94% are removed by the second day. The most common assumption of a drain effect is the avoidance of haematomas.

#### P 67

##### **The safety and utility of anterior cervical fusion with intervertebral cages for 3 or more levels without instrumental stabilization**

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**Introduction:** Anterior cervical discectomy and fusion (ACDF) has become a standard procedure in the treatment of various cervical pathologies. Many centers combine ACDF with ventral plate implantation especially in multilevel surgery because of the fear of possible complications and non-fusion. The aim of this study is to determine the safety and utility of anterior cervical discectomy and fusion with intervertebral cage alone for 3 level surgery or more without implantation of a ventral plate or additional posterior stabilization.

**Methods:** A series of 26 patients underwent ACDF for three levels or more. Mean age at surgery was 64,7 years (range 44-80 years). Twenty-four patients underwent surgery for 3 levels, and 2 patients for 4 levels. Patient demographics, clinical, radiological and follow up data were reviewed and analyzed. Outcome was measured according to a clinical visual analog pain scale (VAS), patient satisfaction index (MacNab's outcome score) and the neck disability index (NDI).

**Results:** There were no intraoperative complications. Follow-up was available in 25 patients at 3 months, at 0,5-1,5 years and at 2-4 years postoperatively. Furthermore, 24 patients were available for FU >4 years. At the last follow-up, 75% of the patients had no/very mild pain in comparison to 20% of patients preoperatively, 58,3% of the patients had no/mild disability at the last FU in comparison to 36% preoperatively. X-ray imaging studies 3 months after surgery showed stable fusion in all patients. The mean NDI improved from 21 to 14,5 at the last follow-up. The patient satisfaction score yielded the following **Results:** 13 excellent, 6 good, 3 fair and 3 poor outcomes.

**Conclusion:** Anterior cervical discectomy and fusion without instrumental stabilization for multilevel cervical disc degeneration represents a safe and effective procedure.

## P 68

**Is There an Association between Cervical Sagittal Alignment Parameters and Neck Disability Before Surgery?**\*F. Vazifehdan<sup>1</sup>, V. Karantzoulis<sup>1</sup>, V. Igoumenou<sup>1</sup><sup>1</sup>Diakonie Klinikum, Wirbelsäulenzentrum, Stuttgart, Germany

**Objectives:** Parameters of cervical alignment, have been associated with clinical outcomes after cervical fusion surgery. However, only few studies have examined the relation between cervical alignment parameters and HRQOL in patients with cervical spine conditions before surgery. To evaluate the impact of cervical alignment parameters on HRQOL, by investigating the relation between sagittal parameters and NDI scores.

**Methods:** Patients admitted in the outpatient department of our institution between June 2016 and June 2018 were prospectively studied. Inclusion criteria were as follows: no prior cervical spine procedures of the cervical spine, established cervical spine examination and imaging studies, recorded NDI scores and cervical alignment parameters.

Patients were grouped: a) depending on whether presenting or not indications for surgery; b) depending on disability levels, based on NDI scores [no disability; mild to moderate; and severe to complete]; and c) by gender. In total, 252 patients [106 men and 146 women; mean age 54.5±12.5 (range, 27-91) years] were included in our study.

In all patients, NDI scores were recorded at the time of admission, and the following radiographic parameters were measured: occiput-C2 angle (C0-2 lordosis), C2-C7 angle (C2-7 lordosis), cervical lordosis (CL, sum of C0-2 and C2-7 lordosis), T1 slope (TS), T1 slope minus C2-C7 angle (TS-CL, cervicothoracic mismatch), and C2-C7 SVA.

The t-test was used for statistical analysis among groups of patients. Pearson correlation coefficients were calculated between pairs of alignment parameters and NDI scores.

**Results:** Surgery was indicated in 86 cases (myelopathy, radiculopathy, stenosis, instability), and non-surgical treatment in 166 patients. Patients indicated for surgery presented only greater C0-2 lordosis (23.2±9.0 vs 19.4±7.9°,  $p=0.017$ ), while NDI scores did not differ significantly. Based on disability levels, again no differences were found in the radiographic measurements among groups of patients. When patients were grouped by gender, men presented significantly lower NDI scores (32±17.4% vs 39.8±19.3%,  $p=0.023$ ) and were significantly younger (51.3±14.1 vs 56.8±10.6,  $p=0.02$ ), while a difference regarding the studied parameters was not found. Correlation analysis revealed that NDI was not associated with any of the radiographic parameters either in patients indicated for surgery, or in those indicated for conservative treatment. Nonetheless, significant relationships were found between the alignment parameters.

**Conclusions:** Cervical alignment does not seem to have a significant impact on patients' quality of life, at least before surgery. NDI scores and cervical alignment parameters do not differ significantly among patients indicated for surgical and non-operative management. However, significant relationships between alignment parameters do exist, indicating the complicate interactions and mechanisms existing in cervical sagittal alignment.

## P 69

**The development and evaluation of a novel lateral mass trajectory for percutaneous application: Anatomic feasibility study with 3D planning and adult cadaver specimen study**\*E. Archavlis<sup>1</sup>, B. Hinke<sup>1</sup><sup>1</sup>Elisabethen Krankenhaus Frankfurt, Interdisziplinäres Wirbelsäulenzentrum Frankfurt, Frankfurt a. M., Germany

**Background Context:** Lateral mass screws are not applicable in percutaneous manner and have limited use for minimally invasive tubular access due to anatomical relationship of the trajectory to the spinous process and lamina. The minimally invasive tubular access, which can be used for lateral mass screws, is limited by the laminar thickness and spinous process height. The purpose of this study was to assess the morphometric feasibilities of a new lateral mass screw fixation

method. The study design included an in vitro anatomical study. The outcome parameters were the anatomic feasibility corridor, the bony anatomical measurements and possible injuries of important anatomical structures.

**Methods:** Far lateral mass screw (FLM) fixation were assessed in 10 human adult cadaver subaxial vertebrae. The anatomic approach was anterolateral with skin incisions behind the sternocleidomastoid muscles. FLM screws pierced the anterolateral aspect of the lateral mass and aimed the spinolaminar junction, starting >5 mm from the caudal and middle edges, angled 0-10° dorsally and 10-12° caudally. Anatomical features and trajectory axis dimensions were measured. After screw insertion, every vertebra was dissected and inspected for cortical breach, vertebral artery, nerve root and plexus injury. The width, height, far lateral mass trajectory angulation and actual screw insertion angles were measured.

**Results:** A total of 60 FLM screws were inserted. No statistical difference in FLM width and height were found between the left and right sides for each level. The overall accuracy of FLM screws was 93.3%. The remaining 6.7% screws had a noncritical breach. There was no statistical difference between the FLM angulation measured in preoperative CT scans and the actual screw trajectory after insertion. There was statistical difference in FLM width between the breach and non-breach screws. No vertebral artery and nerve root or plexus injuries were detected.

**Conclusions:** FLM screw fixation demonstrated anatomical feasibility for subaxial cervical fixation. The feasibility of FLM screw fixation would promise not only a minimally invasive screw placement but also the possibility of C7 and C2 extension and surgery in supine position.

## P 70

**Operative revision strategy after failed cervical disc arthroplasty**\*N. El Hindy<sup>1</sup>, N. Becker<sup>1</sup>, D. Schaefer<sup>1</sup><sup>1</sup>Katholisches Klinikum Lünen/Werne GmbH, St. Christophorus Krankenhaus, Wirbelsäulenzentrum, Werne, Germany

**Introduction:** Cervical disc arthroplasty (CDA) is a commonly used method after ventral discectomy and decompression of the underlying pathology. Expected benefits of CDA in comparison to traditional fusion is motion preservation and possible delay of adjacent segment disease (ASD). Nevertheless CDA failure can develop and there is no gold standard for revision surgery. Here we want to present our operative experience in revising CDA.

**Materials/Methods:** All patients revised because of CDA failure in a single department during the last 4 years were included. Revision surgery strategy was investigated. Furthermore, demographic data (age, sex), preoperative symptoms, treated levels, intraoperative pathological and microbiological results, complications as well as postoperative outcome were evaluated using descriptive statistics.

**Results:** 17 patients were included. 12 (60.6%) female and 5 (29.4%) male patients had a median age of 55 years (range 41 – 65 years). C5/C6 level was predominantly revised with 12, followed by C6/C7 with 4, followed by C4/C5 with 3 and C3/C4 with 1 segment, accordingly. Radicular Pain in 13 (76.5%) patients was the main symptom revealing disc failure, followed by neck pain in 12 (58.8%) and headache in 4 (23.5%) patients. Postoperatively there were only 2 (11.8%) patients with remaining neck pain, which resolved in further Follow Up. No further radiculopathy or headache was detected. CDA was replaced by a PEEK Cage in 2 (11.8%) cases, Titanium cages in 14 (82.4%) and PEEK CAGE + cervical plate in 1 (5.9%) case. An additional dorsal stabilization was performed in 3 (17.6%) cases (2 minimal invasive, DTRAX) and 1 by massa lateralis screws. Microbiological and pathohistological workup was performed in 12 cases which revealed *Corynebacterium freneyi* and *staphylococcus epidermidis* in one case each (8.3%) and pathologically confirmed low grade infection in 5 (42%) cases.

**Discussion:** Clinical signs of CDA failure is radiculopathy and neck pain which resolves by removal of CDA and fusion. Operative revision is mainly performed by ventral fusion with

Titanium cage and rarely by additional posterior fusion. Low grade infection seems to play a role in CDA failure and histological as well as pathohistological workup should be performed.

#### P 71

##### Cervical spondylotic myelopathy: Predicting the surgical outcome

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**Introduction:** Cervical spondylotic myelopathy (CSM) is the most common reason for spinal cord injuries in elderly patients. Up to now, timing of surgical treatment, especially in mild CSM, is still various.

In this study, we analysed demographic data, comorbidities, surgical treatment, number of treated levels and radiological findings such as high signal intensity (SI) on MRI to evaluate the association on the postoperative neurological outcome.

**Material/Methods:** Patients were treated in our department between 2007 until 2016 with CSM were analysed retrospectively. The modified Japanese Orthopaedic Association Score (mJOA) and the Minimum Clinically Important Difference (MCID) were used to define the pre- and postoperative neurological function. Multivariate Analysis was performed for sex, age, comorbidities, high SI on MRI, surgical approach.

**Results:** The study group comprised 411 (36.0 % female, mean age: 62.6 years (range: 31 – 96years). There was a significant improvement of the functional study endpoints after evaluation of the postoperative mJOA Score and the MCID ( $p < 0.001$ ). Surgical treatment, the number of treated levels and the symptom duration did not influence the postoperative outcome. In the multivariate analysis, patients' age, CCI and high SI on T2-weighted MRI were independently associated with a lower pre- and postoperative mJOA Score and the lower postoperative MCID ( $p=0.0005$ ).

**Discussion:** Different surgical treatment, the number of treated levels and the symptom duration until surgery did not affect the neurological outcome. Age, Comorbidities, high SI on MRI are negatively associated with the preoperative status and the postoperative neurological outcome (postoperative mJOA Score and MCID). Therefore, surgery should be performed before a high SI on MRI is present to prevent irreversible damage of the myelon.

#### P 72

##### Pedicle subtraction osteotomy for deformity correction in the upper cervical spine – a technical note

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**Objective:** Kyphosis is the most common deformity of the cervical spine, leading to the development of severe disabilities. In case of fused kyphosis, surgical treatment can be very demanding and often requires multiple step procedures for adequate correction. We present a technique of a single stage pedicle subtraction closing wedge osteotomy (PSO) of C3 to treat a patient with kyphosis with fused C2 and C3 causing spinal stenosis with subsequent myelopathy.

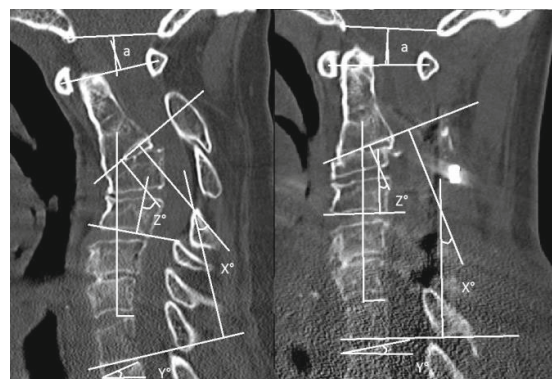
**Methods:** A male 53-year-old patient presented with progressive myelopathy, reaching 6 points on the modified Japanese Orthopaedic Association (mJOA) scale, not able to walk with loss of horizontal gaze. Magnetic resonance imaging (MRI) revealed cervical kyphosis causing stenosis, cord compression and kinking; computed tomography (CT) revealed anterior and posterior fusion of C2 and C3.

**Results:** Surgery included decompression via laminectomy of C2 to C6 in combination of a PSO of C3 and addition dorsal instrumentation from C2-C6. Cervical spinal alignment was corrected, as the C2-C4 Cobb angle was reduced from 48.9° to

20.6° and horizontal gaze was restored. Postoperative MRI demonstrated full decompression of the cord, without kinking of the vertebral arteries. The patient recovered well with restoration of his ability to walk.

**Conclusion:** Single stage pedicle subtraction closing wedge osteotomy in the upper cervical spine, although demanding surgical procedure is an alternative treatment option in selected cases of fused, severe cervical kyphosis. In contrast to multiple step approaches it reduces operating time and may thus decrease complications.

**Fig. 1**



#### P 73

##### Titanium trabecular 3D electron beam melting printed cervical cages promote earlier bone growth: from *in vitro* to surgery, a preliminary report of a prospective analysis and validation

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**Introduction:** Anterior cervical discectomy and fusion (ACDF) is a widely implemented procedure in the treatment of degenerative cervical disc disease. Among other graft options, porous trabecular titanium (PTT) has been shown to be more osteoconductive and effective for biological fixation, presenting some encouraging results mostly in lumbar fusion procedures. PTT has an open-cell metal structure with a low modulus of elasticity similar to human subchondral and cancellous bone leading to better load transfer and minimizing the stress-shielding phenomenon. The objective of this study is to determine the fusion speed as well as the safety and efficiency of 3D printed PTT cervical cages.

**Material/Methods:** We are performing a prospective analysis of 20 consecutive patients suffering from degenerative cervical spine conditions and benefiting from one- to three-level ACDF. Specially designed 3D printed cages made of PTT and modeled by CAD/CAM technology by means of electron beam melting (EBM) (MT Ortho, Aci Sant'Antonio, Sicily, Italy) are implanted with or without an anterior plate support depending on the pre-op findings and presence or absence of myelopathy. Bone grafts are avoided. Fusion rate, segmental height and alignment are assessed via CT-scan at 3 months. The visual analog scale pain score and Neck Disability Index (NDI) are also measured.

**Results:** Preliminary CT-scan results at 3 months show fusion in 83.3% of the patients and initial bony growth through the cage in 100%. Radicular pain and axial pain show an improvement of 89.2% and 75.8% consecutively. An improvement of the NDI by 74.5% is observed. Subsidence or device failure isn't observed. Only one patient required revision surgery for an epidural hematoma on the 3rd postoperative day, otherwise no major complications are noted.

**Discussion:** Special designed 3D EBM printed PTT cages give the bone matrix the possibility to adhere and grow in the cage in order to stabilize the implant rapidly. This faster bony ingrowth seems independent from the diagnosis or additional plating. Their clinical application in cervical arthrodesis appears to be safe and efficient and the cells prove to early colonize the central cavity of the cage, improving bony fusion and thereby confirming the data obtained by recent in vitro studies. Our preliminary impressions need to be validated at the end of our recruitment and follow-up period of 1 year.

#### P 74

##### Comparison of quality of life and kinematics after cervical disc replacement with two non-constrained prostheses

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**Introduction:** Total disc replacement may be indicated in cervical disc degeneration and disc hernia. Non-constrained prostheses are aimed to mimic physiologic kinematics restoring segmental movement and thus preventing stress on adjacent segments and facet joints. The purpose of this prospective study was to analyze clinical and radiographic results of a new cervical prosthesis (Ceradisc) using a double-radius nucleus, mimicking physiologic range of motion and center of rotation of cervical segments to a reference prosthesis with 5 degrees of freedom (Mobi-C).

**Material & Methods:** Two matched-paired patient cohorts were compared: 29 patients were operated at one or two levels with Ceradisc (average age 53.2 years, 18 males, 11 females) versus 47 patients operated with Mobi-C (52.4 years, 32 males, 16 females). The clinical status was assessed at preoperatively, at 6-weeks, 6-months, 1-year and 2-year follow-up using the visual analogue scale (VAS) for neck and arm pain, the Neck Disability Index (NDI) and the Short-Form (SF-12). C2-C7 and segmental lordosis and range of motion (ROM) in flexion-extension of index levels were measured on radiographic images.

**Results:** The average VAS for neck pain was 7.2 in the Ceradisc and 7.4 in the Mobi-C group. A significant postoperative decrease was found in each group: 1.8 and 2.1 respectively at 2-year follow-up ( $p < 0.00001$ ). Arm pain decreased similarly from 7.6 to 1.9 in the Ceradisc group and from 7.2 to 2.0 in the Mobi-C group ( $p < 0.00001$ ). The preoperative NDI was 30.9 and 30.2 in both groups respectively and it increased to 70.2 and 71.1 at 2 years ( $p = 0.00001$ ). The preoperative SF-12 was 37.8 (PCS) and 35.0 (MCS) in the Ceradisc group, 36.9 (PCS) and 34.4 (MCS) in the Mobi-C group. At 2 years, all scores increased significantly ( $p < 0.001$ ): 47.1 (PCS) and 47.5 (MCS) for Ceradisc, 47.5 (PCS) and 47.4 (MCS) for Mobi-C. Preoperative ROM at index levels were 8.2 ° and 8.5 ° respectively in each group. Segmental ROM at 2-year follow-up was 11.1 ° for Ceradisc and 13.7 ° for Mobi-C (NS). Extension was 3.4 ° higher in the Mobi-C group ( $p = 0.014$ ).

**Conclusion:** Both implant designs led to similar improvement of pain and quality of life until 2-year follow-up. Theoretically, the Ceradisc design tends to mimic segmental kinematics in a more physiologic manner leading to less facet impingement due to the double radius of its nucleus in comparison to the Mobi-C design with cranially convex and caudally flat nucleus. Although the Ceradisc is intended to provide a controlled ROM at the index level, the differences between both prostheses were non-significant.

Fig. 1

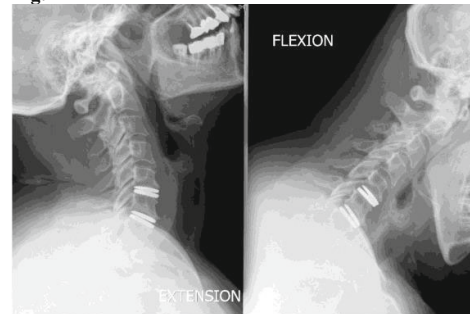
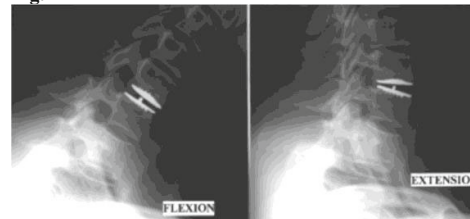


Fig. 2



#### P 75

##### Innovative mesoscopic MRI diffusion parameters for characterization of cervical myelopathy – First results of a prospective observational trial

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**Introduction:** Because of the different disease stages and partially limited correlation of symptoms, electrophysiology and imaging, the optimal timing for an operative treatment is difficult in patients with degenerative cervical myelopathy (DCM). Therefore additional diagnostic tools are required for an early and reliable detection of affected patients. The aim of this study is to obtain new MRI parameters to gain a better association of clinical affection and imaging through a subtle resolution.

**Methods:** Patient data are sampled within a prospective, observational trial.<sup>1</sup> We are using an innovative, machine-learning based, post-processing procedure of high-resolution diffusion MRI to depict subtle spinal cord alterations through a separation of the subvoxel space into 3 mesoscopic compartments: intra-axonal and extra-axonal as well as a free water compartment (*Microdiffusion Imaging*).<sup>2</sup> Axial and radial diffusivities within the tissue compartments and the volume distribution between all 3 compartments are measured through the whole cervical spinal cord.

**Results:** We exemplary show 4 patients in different severity stages of DCM and 1 healthy control. We detected specific volume displacements with a shift from the intra- and extra-axonal to the free water compartment at the level of cervical stenosis in symptomatic DCM patients (Tab.1, blue boxes). Associated there occurred decreasing values for axial intra- and extra-axonal diffusivity (Fig.1). Even for asymptomatic stenosis, we could detect diffusivity alterations at the stenotic level (Fig.1, red line), but without significant volume shifting to the free water compartment so far (Tab. 1, red box).

**Discussion:** These are the first results for novel mesoscopic diffusion MRI parameters to further characterize patients with DCM. Due to the subtle resolution within one voxel associated with intramedullary pathophysiological changes in myelopathy, specific signal intensity

clusters are expected for different stages and duration of the disease. This specific patterns and their associated prognosis with and without operative treatment should be achieved in further evaluations.

<sup>1</sup>Hohenhaus M, et al. Is Microdiffusion Imaging Able to Improve the Detection of Cervical Myelopathy? Study Protocol of a Prospective Observational Trial (MIDICAM-Trial). BMJ Open 2019

<sup>2</sup>Reisert M, et al. Disentangling micro from mesostructure by diffusion MRI: A Bayesian approach. NeuroImage 2017.

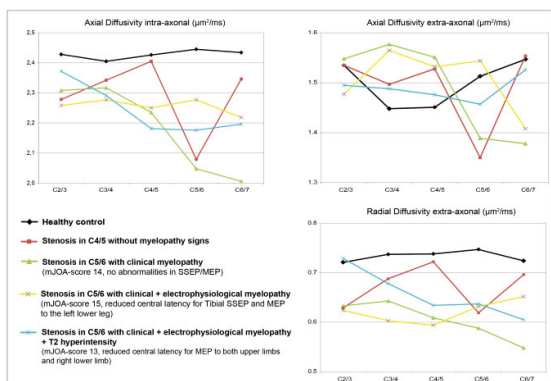
Tab. 1: Changes of the volume distribution of all 3 mesoscopic compartments in different stages of DCM. All symptomatic patients showed an increasing volume of the free water compartment (blue boxes). **Volume changes >10% are marked in bold type.**

Fig. 1: Signal intensity curves of axial diffusivities intra-/extra-axonal as well as radial diffusivity extra-axonal averaged over each cervical spinal cord segment from C2/3 to C6/7 in different stages of DCM.

Fig. 1

Patient	Mesoscopic compartment	Averaged volume fraction		$\Delta$
		C2/3 level	Stenotic level	
Healthy control (*reference level for was defined at C5/6)	intra-axonal	0.341	0.341*	0
	extra-axonal	0.367	0.393*	+0.026
	free water	0.306	0.274*	-0.032
Patient with stenosis in C4/5 without myelopathy signs	intra-axonal	0.352	0.353	+0.001
	extra-axonal	0.136	0.183	+0.047
	free water	<b>0.550</b>	<b>0.496</b>	<b>-0.054</b>
Patient with stenosis in C5/6 with clinical myelopathy	intra-axonal	0.297	0.206	-0.091
	extra-axonal	0.279	0.098	<b>-0.181</b>
	free water	<b>0.446</b>	<b>0.723</b>	<b>+0.277</b>
Patient with stenosis in C5/6 with clinical + electrophysiological myelopathy	intra-axonal	0.398	0.351	-0.047
	extra-axonal	0.230	0.229	-0.001
	free water	<b>0.399</b>	<b>0.444</b>	<b>+0.045</b>
Patient with stenosis in C5/6 with clinical + electrophysiological myelopathy + T2 hyperintensity	intra-axonal	0.210	0.149	-0.061
	extra-axonal	0.377	0.219	<b>-0.158</b>
	free water	<b>0.429</b>	<b>0.654</b>	<b>+0.225</b>

Fig. 2



## P 76 Thoracic kyphosis and lumbar lordosis distribution after idiopathic scoliosis correction using posterior hybrid versus screw instrumentation

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**Study design:** Retrospective observational study.

**Objective:** The aim of this study was to evaluate kyphosis and lordosis distribution, inflexion points and the relationship with proximal junctional kyphosis (PJK) comparing hybrid instrumentation (in situ contouring, derotation) versus screw

instrumentation (thoracic cantilever reduction, lumbar in situ contouring and derotation).

**Summary of background data:** The combination of reduction techniques aims restoring levels of lumbar apex and thoracolumbar inflexion point according to Roussouly alignment types. This approach could minimize the PJK risk after adolescent idiopathic scoliosis (AIS) surgery.

**Methods:** The study assessed coronal curve correction, thoracolumbar and spinopelvic sagittal parameters in 86 skeletally mature adolescents and young adults 2.2 years after AIS correction, comparing a hybrid group (HG n=34) to a screw group (SG n=52). Segmental kyphosis and lordosis distribution, number of vertebrae included in curves, thoracic and lumbar apex, thoracolumbar inflexion point and Roussouly types were modeled using KEOPS software.

**Results:** Global coronal and sagittal correction were similar in both groups. In the SG, lumbar lordosis (LL) decreased from 61.1° to 53.9° (p<0.0001) and matched with pelvic incidence (r=0.69), whereas LL did not change in the HG. Postoperatively, the thoracolumbar inflexion point migrated cranially, resulting in a longer LL in both groups. The postoperative thoracolumbar inflexion point (p<0.0001) and the lumbar apex (p=0.0274) were more caudal in the SG compared to the HG. The PJK rate was 14.7% in the HG and 7.7% in the SG. In patients with PJK, lumbar apex and thoracolumbar inflexion point shifted cranially and were too high according to the Roussouly type.

**Conclusion:** Hybrid and screw instrumentation led to similar global AIS correction, but the use of cantilever reduction in the SG allowed setting the thoracolumbar inflexion point and the lumbar apex lower than in the HG. Cranial migration of these points was identified as PJK risk factor.

Fig. 1

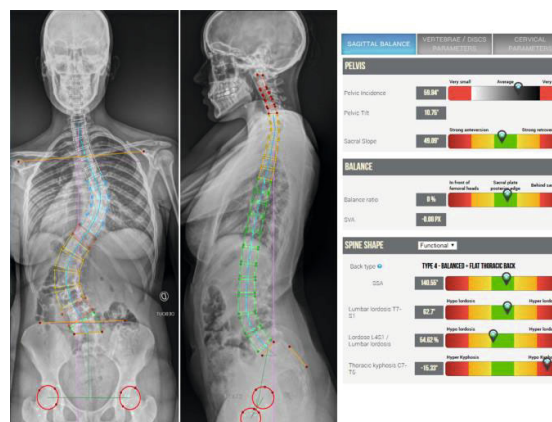
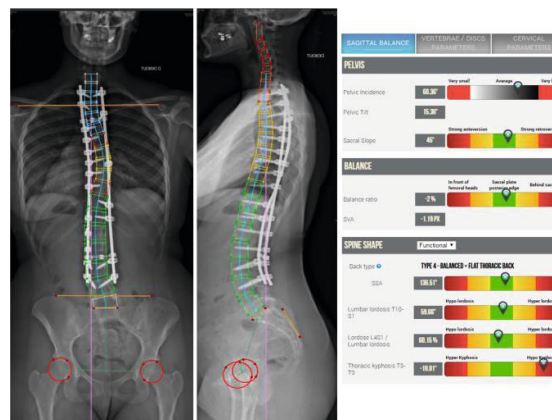


Fig. 2



## P 77

**Quality by quantity – Better outcome by reduction of exposure to radiation in young spine patients**\*S. Krebs<sup>1</sup>, B. Kunze<sup>1</sup>, K. Abudaqqa<sup>1</sup>, C. Schätz<sup>1</sup>, T. Pfandlsteiner<sup>1</sup><sup>1</sup>Orthopädische Klinik Markgröningen, Klinik für Neuroorthopädie, Rückenmarksverletzungen und Skoliosen, Markgröningen, Germany

**Introduction:** Since increasing use of navigation systems especially in deformity surgery exposure to radiation seems to disappear. This happens primarily to children and young people. In spite of carcinogenic references for exposure to radiation in deformity surgery [2] seems by useless perioperative exposure to radiation, as full-dose x-ray and other diagnostic procedures (EOS), especially the intraoperative exposure to radiation in growing patients needless high. Aim of the study is the analysis of exposure to radiation during deformity surgery.

**Method:** In this retrospective monocentric cohort-study 80 consecutive patients have been included. They have got a deformity surgery either by posterior correction spondylodesis or by anterior derotationspondylodesis. In all cases surgery was performed by the same surgeon. The placement of the freehand screws was based on anatomical landmark orientation. Retrospective the intraoperative exposure of patients to radiation, time of surgery and blood loss have been evaluated.

**Results:** At all 61 female and 19 male patients (mean age 22,7 years(y), 12 – 48 y) have been included in this study. 64 idiopathic versus 16 neurogenic scoliosis have been diagnosed. Mean surgical time was 186 min (125 – 215) for average 13,8 screws (6 – 23) with mean blood loss of 265 ml (100 – 780). There were no neurological deficits and no surgical revision. Average exposure to radiation was 21,8 s (7 – 46), this correlates to 1,5 s per screw. The mean surface dose was 61,2 cGy/cm<sup>2</sup> (10 – 152 cGy/cm<sup>2</sup>).

**Discussion:** Due to surgical experience, exposure to radiation during scoliosis surgery could be reduced to 1,5 s per screw. Compared to other technics, as percutaneous pedicle screw placement (29 s per screw) exposure to radiation is much less [1]. Thus in addition to new technical solutions reduction of patient exposure to radiation can also be solved by exact placement of pedicle screws by orientation to anatomical landmarks.

## P 78

**Predictive risk factors for curve progression in adolescent idiopathic scoliosis – a systematic review**\*M. Lenz<sup>1</sup>, M. Farshad<sup>2</sup>, P. Fürtstahl<sup>2</sup>, J. Bredow<sup>1</sup>, P. Eysel<sup>1</sup>, M. J. Scheyerer<sup>1</sup><sup>1</sup>Uniklinik Köln, Orthopädie und Unfallchirurgie, Köln, Germany<sup>2</sup>Uniklinik Balgrist, Zürich, Switzerland

**Introduction :** Idiopathic scoliosis, as defined by a >10° curvature of the spine in the frontal plane, is one of the most common spinal deformities. Age, initial curve magnitude and other parameters define whether a scoliotic deformity will progress or not. These factors have been identified, but their interactions and amount of individual contribution is not fully elaborated and was aim of this systematic review.

**Methods :** A systematic literature search was conducted in the common databases using specific MESH-terms. Inclusion criteria were defined by the scientific nature and the relation to the research question according to the PRISMA scheme. Cell-specific or genetic studies were excluded from the analysis.

**Results:** Overall, 30 investigations with 6947 patients were identified by literature search including patient-specific as well as radiological parameters. The mean age of patients was 12,8 years. Patients specific risk factors were age (age at diagnosis <13 yrs) , positive family history, bone quality and bone mineral status (<110mg/cm<sup>3</sup> in qCT) as well as speed of growth (spinal growth velocity >7mm/year with peak SGV at 12,1 yr). Relevant radiological criteria that could provide an indication of severe curve progression included the status of ossification or skeletal age, usually marked by Risser stages or Sanders Maturity Scale, the initial extent of the Cobb angle (>25° risk of progression) and curve type (thoracic, thoracolumbar, lumbar or/and single or

double (with thoracic curve as risk factor with annual-curve-progression >6,8°/yr) as well as rib-vertebral angle (>65° after brace treatment). Following the criteria, patients with initial Cobb >25°, premenarche status and skeletal immaturity (Risser <1, Sanders <5, triradiate open) and thoracic or double-thoracic curves had highest risk to severe curve progression.

**Discussion :** This systematic review summarized the current state of knowledge as basis for creation of patient-specific algorithms for risk calculation for progressive scoliotic deformity. Patients with larger curves while skeletally immature have the highest risk for severe curve progression.

## P 79

**The ventral Derotationspondylodesis – a therapeutic option in minimal invasive Deformity Surgery**\*T. Pfandlsteiner<sup>1</sup>, B. Kunze<sup>1</sup>, C. Schätz<sup>1</sup>, S. Krebs<sup>1</sup><sup>1</sup>Orthopädische Klinik Markgröningen, Neuroorthopädie, Markgröningen, Germany

**Introduction:** Some years ago the thoracic anterior approach to the spine has been avoided because of high risk of complications and morbidity due to the approach by the most of the spine deformity surgeons. But since discussion of tethering appeared paradigm changed.

**Method:** Aim of the study is the retrospective analysis of peri- and postoperative complications, functional outcome, and approach morbidity of our own cases of ventral derotation spondylodesis (VDS). Improvement of surgical technic (skin incision length, reduction of time for surgery, reduction of blood loss) was evaluated over the years by the individual surgeon learning curve.

**Results:** 130 VDS from 2008 till 2019 (84% female, mean age 16,7y). 29 patients have got a combined surgery either in the same hospital stay, or like e.g. in early onset scoliosis with time lag of some years.

In 101 cases with only anterior surgeries, 2/3 have been Lenke 5C-curves. In the thoracic curves majority were Lenke 1A or 1B and few cases Lenke typ 2 curves. The mean length of fusion were 5 segments. The Cobb angle was reduced from 55° (40 – 100°) to 11° (0 – 48°), the sagittal alignment was improved in all cases. The blood loss during surgery was Ø 372ml, without any need for blood transfusions, Ø time of surgery was 224 minutes. The skin incision length was very short with Ø 10,8cm. Morbidity due to the approach like postthoracotomy syndrome or disturbances of pulmonary function have not been seen in the follow up. The mean follow up was 4,6y (3 months to 1,2 years). There was 1 case of rod breakage in the beginning due to a one-rod system used in a thoracolumbar curve, without surgical revision and without any complaints from the patient. In another case microscopic instability occurred, and because of complaints an additional posterior instrumentation was necessary.

**Discussion:** The VDS is approved for many years, and since the introduction of the double-rod system for thoracolumbar curves a very safe surgical method for treatment of Lenke typ 5C and 1A curves. By using the correct surgical technic, very low morbidity is seen. The benefit for the patient is the minimal invasive approach combined with very low blood loss during surgery and short hospital stay. Significant restrictions in daily activity and sport activities are not seen in the longtime follow up. Compared to other surgical deformity treatments, by the minimal invasive VDS an additional rib hump or lumbar bulge can be corrected by derotation. In thoracolumbar curves due to better rotational stability only double-rod systems should be used.

## P 80

**Dorsal correction spondylodesis release by dual vertebral column resection in a young patient with split spine, lumbosacral scoliosis and associated anterior neuroenteric cyst: a case report**\*F. C. Stengel<sup>1</sup>, I. C. Hostettler<sup>1</sup>, B. Meyer<sup>1</sup>, H. Koller<sup>1</sup><sup>1</sup>Klinikum rechts der Isar, Neurochirurgie, München, Germany

**Background:** Surgical correction of syndrome-related and congenital scoliosis is challenging. Anatomical variations further

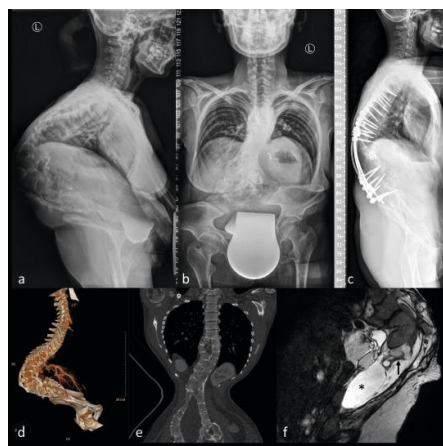
complication selection of the appropriate surgical strategy. We present the surgical strategy and results of correcting in an unique congenital deformity with split spine, thoracolumbosacral kyphoscoliosis and anterior neuroenteric cyst not previously reported in the present literature.

**Methods:** An ambulatory 15 years-old adolescent patient presented with progressive congenital kyphoscoliosis ( $120^\circ$ ) and associated pain, posture-related dyspnea, and difficulties in ileostoma care due to its location and bend trunk. Imaging revealed an anterior spinal dysraphism with lumbar split spine and anterior neuroenteric cyst (Fig. a, b, d, e, f). These characteristics of our patient mimic those described for Currarino-syndrome. No surgical correction has yet been described in similar constellation with severe kyphoscoliosis. Surgical approach was challenging given the split spine at the thoracolumbar apex, the elevated risk for durotomy due to adhesions to the osseous structures and neuroenteric cyst, the loss of anatomical landmarks in the lumbosacral area impeding pedicle screw insertion, and rigidity of the deformity. We therefore planned a two-staged approach. During the first intervention, pedicle screws were inserted by free-hand technique in the segments above the split spine, while screw-insertion was navigated in the split spine area. After mobilization of the dural sac and neurolysis at the periapical region, a dual posterior vertebral column resection (pVCR) was carried out at the T12 level under neuromonitoring in a second step. The anterior neuroenteric cyst (fig. f) was mobilized from the right-sided anterior osseous elements of the split spine. We achieved correction using a 4-rod alternating correction technique.

**Results:** Postoperatively, the patient did not have any motor deficits. Biplanar full-spine radiographs showed restoration of global balance in both sagittal and coronal planes with a total of  $60^\circ$  correction at the VCR level. The patient gained 7 cm in height. The achieved correction was preserved at follow-up (fig. c). The patient reported improved ileostoma care due to the reduced rib-pelvic impingement as well as an increase in sportive activity due to improved breathing ability.

**Conclusion:** Extensive preoperative surgical planning and intervention using a dual pVCR for rigid congenital spine deformity resulted in an excellent radiographic clinical outcome. Combination of free-hand pedicle screw fixation and navigation techniques enable safe performance of spinal deformity surgery. This is the next step in advanced spinal deformity surgery. A treatment algorithm for combined application of free-hand and navigated pedicle screw fixation will be presented.

Fig. 1



P 81

**Does the administration timing of tranexamic acid have an influence on intraoperative blood loss in spinal surgery?**

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**Purpose:** Complex procedures in spine surgery (such as dorsal or ventral fusion of the thoracolumbar spine, ventral cervical fusions and thoracolumbar vertebral body replacements) are accompanied by a high amount of intraoperative blood loss which often results in the need of blood transfusions. Prolonged stay at the hospital as well as on the intensive care unit are cost-sensible factors.

**Methods:** This study presents a retrospective analysis of 138 patients treated in our spine surgical ward in 2018. The aim was to detect a correlation between intraoperative blood loss, length of intensive care unit treatment and overall hospital stay depending of the administration timing of 1 gram tranexamic acid (TXA) intravenously. The cases were divided in 3 groups: group 1 received TXA within the first hour, group 2 between the first and second hour of the procedure and group 3 after the second hour.

**Results:** The intraoperative blood loss of group 1 was 826.92 ml (the lowest) and 1700 ml in group 3 (group 2 1500ml). Both group 2 and 3 stayed the less time on the intensive care unit in comparison to group 1 but needed more blood transfusions and stayed approximately 3 times longer at the hospital overall.

**Conclusion:** Tranexamic acid can reduce intraoperative blood loss by nearly half and the hospital stay by two thirds as well as blood transfusions significantly but seems to have no effect on postoperative intensive care necessity.

Fig. 1

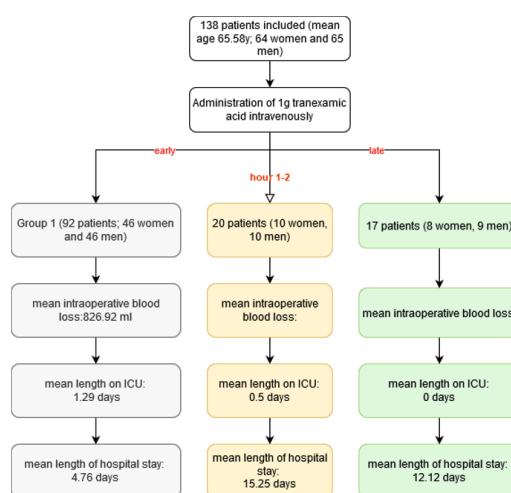
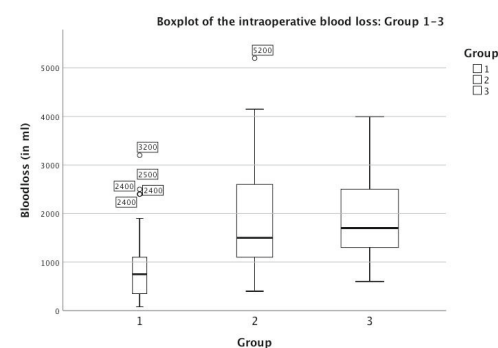


Fig. 2



P 82

**ACQUIRED "IATROGENIC" SPONDYLOLYSIS: COULD BE ASSOCIATED WITH SPINOPELVIC SAGITTAL ALIGNMENT?**

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**Purpose:** We studied patients presenting this rare entity, with the purpose to investigate the incidence, imaging findings, patients"

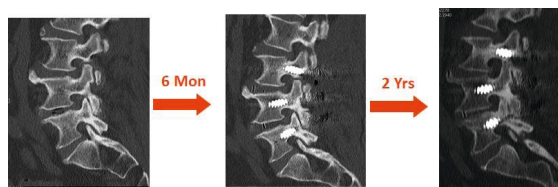
clinical characteristics, and to provide as well an interpretation of the mechanisms that may lead to this phenomenon. The presented working hypothesis, regarding etiology, suggests that there is a relation between variations in spinopelvic sagittal alignment and acquired spondylolysis.

**Methodology:** Retrospective study of patients presenting acquired spondylolysis after posterior lumbar fusion (in TLIF technique) due to degenerative spine conditions without prior evidence of spondylolysis or spondylolisthesis. Data acquired from the electronic registry of our department revealed that, during the study period (5 years; January 2010 – January 2015), 714 patients were offered mono- or bisegmental posterior lumbar fusion due to degenerative spine conditions. Of these, 83 patients presented spondylolysis and/or spondylolisthesis prior to surgery and were excluded. We recognized six cases of acquired spondylolysis in three female and three male adult patients of a mean age of 75 years; age range, 68 – 80 years. Spondylolysis occurred at a mean time of 43 months after surgery; range, 26 – 60 months. Both the postoperative defect and the preoperative intactness of pars interarticularis were documented with computed tomography (CT) scans. All standard spinopelvic radiological parameters were measured in all patients.

**Results:** The incidence of acquired spondylolysis was 0.95% among patients with short-segment lumbar fusion. Spondylolysis occurred at pars interarticularis of L5 vertebra in all cases, with three patients presenting a unilateral and three patients a bilateral pars defect. At presentation one or more of the following symptoms were present: residual low back pain, sciatica, weakness, and sensory deficits of L5 distribution. Of the work up studies performed, the definite diagnosis of spondylolysis could be established only with CT scans, especially in the sagittal reconstruction images. Patients presented high-grade Pelvic Incidence (PI) with a vertically orientated sacral endplate, while lordosis (LL) was found 9 degrees greater and PI-LL mismatch 9 degrees lower than the respective optimum values, indicating a non-harmonized alignment.

**Discussion:** Acquired spondylolysis represents a rather uncommon complication of spine surgery, with an incidence of less than 1%. Patients presenting late symptom recurrence, along with great sacral slope and suboptimal lumbar lordosis, in the setting of high pelvic incidence, should be highly suspected with acquired spondylolysis. If plain radiographs are inconclusive, CT scanning of the spine should be performed with special attention given to the sagittal reconstruction images. Detailed preoperative planning and optimal sagittal alignment after surgery are of great importance, and can prevent from complications rare and frequent as well.

**Fig. 1**



### P 83

#### Postoperative changes in sagittal balance after therapy with new craniocaudal expandable implant for the minimally invasive reconstruction of osteoporotic vertebral body compression fractures: 3 years of experience with 150 patients

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**Objective:** We present the surgical technique and patient data of 150 patients with three years follow up treated for osteoporotic compression fractures of the thoracic and lumbar spine. Patient data were collected prospectively. The aim of this study is to evaluate the restoration of sagittal balance with this technique and the clinical outcome for the patients.

The aim of this study is to evaluate the changes in sagittal balance and their effect on the clinical outcome of 150 patients with osteoporotic compression fractures of the thoracic and lumbar spine, who were treated with a new craniocaudal expandable implant for minimally invasive reconstruction of vertebral body fractures. Patient data were collected prospectively.

**Methods:** We treated 150 patients for 165 spinal osteoporotic fractures with an age ranging from 46–89 years. OF-Classification of osteoporotic vertebral body fracture (OF 0–5) was type OF 0 (24), OF 1 (37), OF 2 (31), OF 3 (29), OF 4 (38) and OF 5 (6). All implants were percutaneous transpedicular. For augmentation PMMA or a combination of PMMA / hydroxyapatite was used. All patients had a preop clinical examination, spine x-ray, CT and MRI as well as a postop clinical examination and x-ray after 1 month, 1 year and 3 Year. For each patient we measured the height of the vertebral body as well as the kyphosis angle of the fractured vertebral body. Restoration of the spinal profiles was assessed with spinal x-ray. All included patients had a 3-year follow up.

**Results:** Within the 3 years follow-up period, the reduction of pain according to VA-scale was 71%. Increase of vertebral body height was 15% after the procedure and 11% after 3 years. The kyphosis angle was -6° prior to surgery and -4° 3 year later. The restoration of the sagittal balance was detectable in 89% of the cases. Sagittal vertical axis (SVA): Pre-op: 6,98±3,5 cm, Post-op: 5,01±2,93 cm. Cement leak was seen in 71 Patients (40,6%) and incorrect position of the implant in 3 Cases (1,8%), in all of them without neurologic deficit. There was no reoperation in the same segment within 3 years.

**Conclusion:** The presented method with a craniocaudal expandable implant is efficient, safe and provides excellent results after 3 years follow up. We achieved long lasting reduction of pain and pain medication in our patients. This technique allows a restoration and improvement of sagittal balance in most of the cases.

### P 84

#### Revision rates after thoracolumbar spine surgery in patients with Parkinson's disease – a single-center retrospective study

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**Introduction:** Parkinson's disease (PD) is the second most common neurodegenerative disorder affecting 1% of the population from sixty upwards. Postural imbalance in patients suffering from PD is a ponderous risk factor for developing degenerative spinal disease. With rising life expectancy in developed countries, the number of patients with PD requiring spine surgery are on the rise. In this study we compared revision rates after thoracolumbar spine surgery and the underlying mechanism between patients with and without PD.

**Material/Methods:** Patients with PD who underwent thoracolumbar spine surgery in our neurosurgical department with and without spondylolysis were identified between 2008 and 2019. 118 patients without PD who underwent dorsal stabilization in our department between 2012 and 2019 served as reference cohort. Patients with infections or tumors of the spine were excluded from this study.

**Results:** A total number of 82 spine surgeries were carried out on 53 patients with PD. The overall revision rate was 36%. Patients who underwent spondylolysis had a strikingly higher revision rate of 53%. Compared to patients without PD with an overall revision rate of 11% the risk for reoperation was around nine times higher for patients with PD (Odds ratio 9.09; p=0.0002, Fig. 1). The number one cause of revision surgery in 58% of the cases was material failure. Additionally, the number of days in hospital was significantly higher for patients with PD (21 days vs 14 days, p=0.0035, Fig. 2).

**Discussion:** A significantly higher rate of revision surgery could be depicted in patients with PD especially when spondylolysis was necessary and hardware failure was the most frequent indication for revision. Moreover, the length of hospital stay is also significantly higher in patients with PD. Because of the complexity of this patient cohort spine surgeries on patients with PD should only be performed in specialized centers with particular attention to postural instability.

Fig. 1

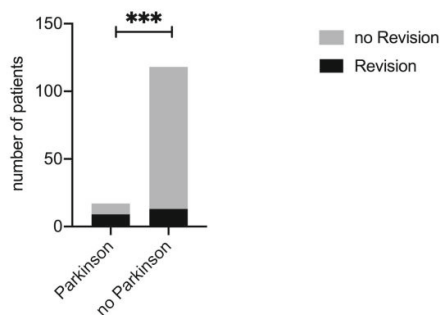
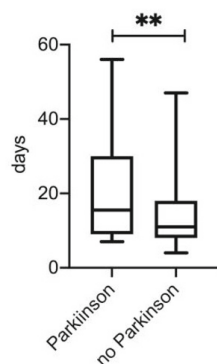


Fig. 2



## P 85

## Single-centre case series of patients with myelon herniation – hospital cohort study, review of the literature and pooled analysis

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## Background

Spinal cord herniation (SCH) is a rare cause of progressive myelopathy and Brown-Séquard-Syndrome. There is still little information available on functional outcome after SCH treatment.

**Methods:** We retrospectively analysed functional outcome in patients with SCH treated in our department between 2009 and 2020. We conducted a systematic search using PubMed, MEDLINE as well as EMBASE and performed pooled analysis including our cohort as well as other published studies including patients with SCH.

**Results:** Our hospital cohort included 17 patients of which 9 were treated surgically. Mean age was 55.2 years and 66.7% of the patients were female. In 4/9 patients (44.4%) the neurological state remained stable after surgery. Four patients improved (44.4%) and one deteriorated after surgery (11.1%). In our pooled analysis, 108/145 (74.5%) of the patients improved, 34/145 (23.4%) remained stable and 3/145 patients deteriorated (2.1%). Among the available data of nine cohorts, mean recovery rate measured by the JOA score was 36.6% (SD 14.4). In our pooled multivariable model preoperative JOA score was associated with improved (or rather worse) functional outcome (OR 0.83, 95%CI 0.73-0.97,  $p=0.02$ ).

**Conclusion:** Our data shows that patients who are treated surgically have a higher rate of improvement and acceptable perioperative morbidity. Lower preoperative JOA score decreases chances of improved functional outcome on follow-up. A prospective, multicentre study with standardized periods of follow-up and clearly defined outcome variable would significantly add to

the understanding of this disease as well as further help in informing and guiding patients as well as their relatives.

## P 86

## Correlation of the Eysel and Peters classification of spondylodiscitis with cross-sectional imaging techniques

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**Introduction:** The MRI represents the gold standard of imaging diagnostics in spondylodiscitis, in case of contraindications or in addition a CT can be performed. A common, validated classification for cross-sectional imaging procedures is missing so far. The classification according to Eysel and Peters is a purely radiological classification. In the present study it will be examined whether its criteria can serve as a basis for the development of a MRI/CT classification for spondylodiscitis.

**Methods:** From a prospective spondylodiscitis registry (2008 to 2019), lateral x-rays of the spine in a upright position and MRI or CT images of 164 patients were retrospectively examined by spinal surgeons and classified according to the Eysel and Peters classification. The respective intra-rater reliability (Cohen's Kappa) was calculated and the results examined for statistically significant differences (U-test).

**Results:** Thirty of the 164 patients (18%) were radiographically assigned to grade 1, 47 (29%) to grade 2, 84 (52%) to grade 3 and one patient to grade 4. Eleven of the 97 patients (11%) with MRI were assigned to grade 1, 42 (43%) to grade 2, 44 (45%) to grade 3 and none to grade 4. Eight of the 107 patients (7%) with CT were classified as grade 1, 51 (48%) as grade 2, 47 (44%) as grade 3 and one as grade 4. Intra-rater reliability (X-ray → cross-sectional image) was substantial ( $\kappa=0.62$ ;  $p<0.001$ ). There was no statistically significant difference between the grading of the radiographs and the cross-sectional images ( $p=0.74$ ).

**Discussion:** The criteria of the radiological Eysel and Peter's classification for spondylodiscitis can be transferred to cross-sectional imaging procedures. The classification can thus serve as a basis for a more detailed classification, which should also take into account signal changes and KM accumulation of vertebral body, intervertebral discs and perivertebral tissue, as well as epidural and psoas abscesses. The different imaging modalities of x-ray and cross-sectional images (standing vs. lying) seem to have only little influence on the representation of destruction-related kyphosis.

## P 87

## Methicillin-resistant Staphylococcus aureus caused haematogenous spondylodiscitis – Incidence, risk factors, management and outcomes

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**Introduction:** The incidence of haematogenous spondylodiscitis (SD) is increasing. This might be caused by an increase in susceptible populations and an improved accuracy in diagnosis. Staph aureus as causative organism is accounting for 30-80%. MRSA SD is also increasing with 10-30% of all staph aureus isolates.

**Patients and Methods:** Retrospective analysis of prospectively collected data of patients with SD between 2005 and 2015. The study revealed 600 patients with hematogenous SD after exclusion of cases with postoperative or wound infections. A causative organism could be identified in 67.5%. Staph aureus was isolated in 171 patients. The aim of this study was to collect the cases of MRSA SD. Demographic, clinical, radiological and laboratory data as well as management and outcomes were analysed.

**Results:** In 30 patients (17.5% of all staph. aureus) MRSA SD was found, 8 females and 22 males with a mean age of  $65\pm 10.9$  years (37-81); 93.3% of them > 50 years. 70.3% had ASA-Score III and IV, 33 patients were obese or overweight. Heart disease was present in 22 patients, DM in 18, renal insufficiency in 17, peripheral vascular insufficiency in 16 and in 26 cases another site of infection was

diagnosed. 19 patients had received prior antibiotics for an average of  $24.4 \pm 17.8$  days (2–60). The pre-surgical interval ranged from 5 to 90 days (mean  $33.1 \pm 23.6$ ). Neurological deficits were present in 22 patients (73.3%), fever was found in 20 (in 17 of them blood cultures were positive) and a septic manifestation in 10 patients. The lumbar spine was affected in 56.7%; in 80% only one segment was affected while in 5 patients multifocal (non-contiguous) infection was found. In 27 patients, epidural abscess was detected, 5 patients had psoas abscess. Preoperative laboratory revealed mean CRP of  $161.3 \pm 105.8$ , WBC of  $12.1 \pm 6.2$ , ESR of  $104.8 \pm 23.4$ . In 3 patients (10%), more than one organism could be isolated. Surgical management was proceeded in 29 patients; an anterior-posterior approach was necessary in 26 of them. In 3 patients recurrent infection was detected and treated surgically. Four patients died due to septic shock, 2 patients after cardiac infarction, one of renal failure and one due to respiratory failure (in-hospital mortality: 26.7%). 78% reached a neurological improvement of at least one grade. Antibiotic therapy lasted more than 12 weeks in 17 patients (mean period:  $70.6 \pm 36.4$  days). Vancomycin was used in 19 patients, in 11 patients a combination of antibiotics was necessary.

**Conclusion:** MRSA SD is still a devastating condition. It is associated with significant morbidity and mortality. Clinical suspicion should remain high as prompt diagnosis and treatment are essential. At present, we think that insufficient emphasis is placed on the possibility of MRSA infection in individuals placed on empirical therapy for SD. We think that all patients with recent healthcare system exposure with SD without a positive culture should receive antibiotics that cover for MRSA.

#### P 88

##### **Destructive *per continuitatem* spondylodiscitis after endovascular abdominal or thoracic aneurysm repair (EVAR/TEVAR): rare and untreatable?**

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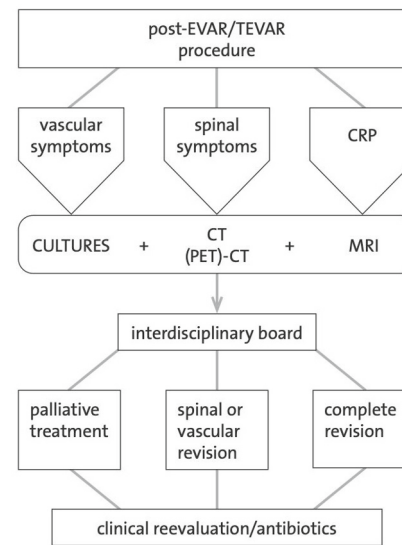
**Introduction:** Very few publications have previously described spondylodiscitis as a potential complication of endovascular aortic procedures (EVAR/TEVAR). We present to our knowledge the first case series of spondylodiscitis following EVAR/TEVAR based on our data base. Particular focus was laid on the complexity of disease treatment and grave outcome perspectives from a spine surgeon's point of view in this seriously affected patient group.

**Materials and Methods:** A retrospective analysis and chart review was performed in two clinics. In 11 out of 284 consecutive spondylodiscitis patients who underwent EVAR/TEVAR procedure and developed destructive *per continuitatem* Spondylodiscitis.

**Results:** All 11 patients had single or more level destructive spondylodiscitis adjacent to the thoracic/lumbar stent graft. In mean 4 surgeries were performed per patient to treat this rare complication. Six out of eleven patients (55%) died within 6 months of the first identification of *per continuitatem* spondylodiscitis. In 4 patients due to persisting infection of the graft and recurrence of the abscess formation, a persisting fistula from an anterior approach to the skin was applied. A treatment path to interdisciplinary assessment with all therapy options is created.

**Conclusions:** Destructive *per continuitatem* spondylodiscitis is a rare and severe complication post-EVAR/TEVAR. Clinical and imaging features of the anterior paravertebral disease and anterior vertebral body involvement suggest the direct continuous spread of the graft infection to the adjacent vertebral column. The mortality rate of these severe infections is extremely high and treatment with a permanent fistula may be one salvage procedure.

**Fig. 1**



#### P 89

##### **Impact of microbiological diagnosis on the clinical course of spondylodiscitis**

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**Introduction:** Spondylodiscitis is a serious disease of the spine, usually caused by bacterial pathogens and often showing a disastrous clinical course. This study sought to recognize differences in clinical disease manifestations of spondylodiscitis depending on the causative bacterial species. Our aim was to generate and adapt specific therapies for the future.

**Methods:** We performed a retrospective evaluation of all spondylodiscitis cases in our clinic between 2013 and 2018. 211 patients were included, in whom bacterial pathogens were detected in 80.6% (n=170/211). We collected the following data; disease complications, comorbidities, laboratory parameters, localization of the infection (cervical, thoracic, lumbar, disseminated), psoas and epidural abscess occurrence, length of hospital and intensive care unit stay and 30-day mortality rates depending on the causative bacterial species. Differences between bacterial detection in blood culture and intraoperative samples were also recorded.

**Results:** Pathogen detection in blood culture showed positive results in 46% (n=97/211) of the patients, in intraoperative samples microbiological diagnosis was successful in 63.5% (n=134/211). Both entities were positive in 64 patients (30.3%). In 78 cases, only intraoperative specimens were positive, in 28 cases bacteria were recovered from blood cultures, but not from intraoperative specimens. *Staphylococcus aureus* was the most frequently detected pathogen in blood culture and intraoperative specimens, followed by *Staphylococcus epidermidis*. *S. aureus* was significantly more often isolated cervically in blood cultures (p=0.026) and intraoperative tissue (p<0.001) than in other localizations of the spine. Bacteremic *S. aureus* infections were associated with a significantly increased mortality in patients with spondylodiscitis (31.4% vs. overall mortality of 13.7%, p = 0.001), more frequently developing complications such as shock, liver failure, pneumonia and myocardial infarction. Comorbidities, psoas and epidural abscesses, length of stay in hospital, gender and

laboratory parameters all showed no significant differences depending on the bacterial species.

**Conclusion:** Blood culture significantly improved the diagnostic yield, thus underscoring the need for a structured diagnostic approach. *S. aureus* spondylodiscitis was associated with increased mortality and a higher incidence of complications. Interestingly, this effect only became evident in spondylodiscitis with systemic involvement.

## P 90

### Minimally invasive surgical management of thoracic spondylodiscitis in elderly patients; thoracoscopic debridement and fusion combined with posterior percutaneous fixation

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Spondylodiscitis affects the thoracic region in about 20 % of spine infections and can lead to severe neurological deficits and even death if inadequately treated. Old patients with multiple comorbidities are more vulnerable and have more complicated clinical progression. The open surgical approaches are associated with complications and can lead to a prolonged hospital stay and lower surgical results. Minimally invasive surgery aims to reduce complications, especially in elderly patients. In this study, we reviewed the clinical and surgical results of a combined minimally invasive anterior thoracoscopic debridement and fusion and posterior percutaneous fixation in elderly patients with thoracic spondylodiscitis.

**Materials and Methods:** From 2005 until 2016, a total of 225 patients were managed through anterior thoracoscopic debridement and fusion in prone position combined with a posterior percutaneous fixation for the treatment of thoracic spondylodiscitis, 92 of them were older than 65 years and are the material of this study. Preoperative clinical and laboratory investigations, operative profile, and postoperative follow up were analyzed.

**Results:** There were 54 males and 38 females with a mean age of 74.12 years (66 to 88). The presentation was pain in all patients, fever in 64 (65%), neurological deficits in 27 (29.3%) 7 of them was complete, and sepsis with cardiovascular instability in 12 patients (13%). Preoperative mean VAS was 7.4 and ODI was 26.4. Blood culture was positive in 22 patients (24%), the mean preoperative CRP was 142.5 (48 to 458), and the mean WBC was 14.6 (range 4.5 to 24.7). Preoperative antibiotics were used in 20 patients (22%) for 2–4 weeks. In 47 patients (51%) an epidural abscess was found, and in 15 (16.3%) there was multilocular.

The mean operation time was 226 minutes (120 to 310), and the mean blood loss was 685 ml (100–2500). Thoracoscopy was done from the right side in 50% of the cases. In 20 cases a corpectomy was necessary due to osteolysis. There were no intra-operative complications. *Staph. Aureus* was the most common organism in 35 patients, followed by *staph. Epidermidis* in 12 patients. In 74 patients, antibiotic therapy was given for 12 weeks, in 18 patients for eight weeks (negative microbiological results). After two weeks the CRP usually fell to a mean of 36 and WBC to 7.5. After a mean follow up of 38 months (6 to 132) there was no recurrence of infection, but reoperation was necessary in 5 patients: due to adjacent segment infection in 3 and due to posterior screw loosening in 2 cases. In the last postoperative follow up the mean VAS was 3.2, and ODI was 10.8.

## Conclusions

Thoracoscopic debridement and fusion in the prone position, combined with percutaneous fixation, is a safe and effective approach for the management of thoracic spondylodiscitis in elderly patients. The prone position allows the combined anterior and posterior approach without the need of patients repositioning during surgery

## P 91

### Local differences in cause and treatment of spondylodiscitis

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**Introduction:** Spondylodiscitis is a serious condition of the spine with very different treatment algorithms lacking standardized approaches due to regional and patient related differences that must be accounted for.

**Methods:** We identified 135 patients (66 vs. 67) who were treated for spondylodiscitis between 05/2008 and 12/2015 from two centers of primary care, one university hospital (UVH) and one non-university hospital (NUH) in two different geographic regions of Germany. Retrospective Data analysis was performed (Chi<sup>2</sup>, t-test), the study was assigned the number WF-013/20 by the local ethics committee.

**Results:** Patient age median was 70y (19y–93y) NUH patients were older mean 69.0y vs. 63.4y (p<0.05), gender was equally distributed, 40.3% female NUH vs. 35.3% UVH (p=0.55). 8.5%/7.5% had received spinal infiltration therapy (p=0.94) and 17.9%/17.6% (p=0.90) spinal surgery prior to infection. 61.5% NUH vs. 47.1% UVH presented an acute onset (p=0.12) with pain being the leading symptom in 100% of NUH and 86.4% of UVH patients. Neurological deficits showed in 11.5% vs. 19.7% (p=0.23). CrP elevation was found in 93.9% vs. 95.6% of all patients (p=0.67), contrary to leukocytosis found in only 44.3% vs. 39.7% (p=0.60). Ultimately 23.9% of NUH patients required spinal fusion vs. 83.8% of UVH patients, 9.0% vs. 1.5% were treated conservatively (p<0.001). Preoperative antibiotics were administered in 29.8% of NUH and 55.2% of UVH cases (p<0.01). Overall antibiotics were administered i.v. for 9.8±4.4d NUH vs 29.6±22.9 d UVH (p<0.001), correspondingly treatment p.o. was continued for 12.4±3.3 weeks NUH vs. 7.2±5.9 weeks (p<0.001). Bacterial specimen were resistant to mean of 3±2 groups of antibiotics in both cohorts. 9.0% NUH vs. 20.6% UVH showed no resistances to antibiotics (p=0.06). Distribution of bacterial specimen was significantly different between both cohorts (Chi<sup>2</sup> p<0.05).

**Discussion:** Different centers treating spondylodiscitis cater to different patient collectives and are subject to a locally different bacterial flora. The antibiotic treatment can be successful in both settings with different durations of i.v. / p.o. ratios if adapted to the local environmental variables, also the extent of surgery necessary may be quite different depending on the respective patient collective of the treating institution. Hospitals should therefore individually assess their patients and regional bacteria to develop in-house standard procedures for their patients.

## P 92

### Obesity in spontaneous spondylodiscitis: a relevant risk factor

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**Purpose:** Spondylodiscitis is a serious disease and potentially life-threatening. Obesity is a risk factor for any infection and is increasing worldwide. The aim of this study is to identify risk factors for obese patients suffering from spondylodiscitis.

**Methods:** Between December 2012 and June 2018 clinical records were screened for patients admitted for spondylodiscitis. Two-hundred and twelve adult patients suffering from spondylodiscitis were included in the final analysis. The mean age was 64.6±14.8 years. Patients were grouped as BMI ≥30 kg/m<sup>2</sup> and BMI <30 kg/m<sup>2</sup>. Patient data concerning demographics, comorbidities, surgical treatment, laboratory testing, and microbiological workup were analyzed using an electronic database.

**Results:** Seventy-seven patients had a normal weight (body mass index [BMI] 18.5–24.9 kg/m<sup>2</sup>), 65 were pre-obese (BMI 25–29.9

kg/m<sup>2</sup>), 49 patients were classified as obese (BMI  $\geq 30$  kg/m<sup>2</sup>). Obese patients had a higher revision surgery rate ( $p=0.08$ ; Odds ratio (OR) 2.8, Relative Risk (RR 2.2)), were younger and showed a higher rate of abscesses, neurological failure and postoperative complications. A different bacterial spectrum dominated by staphylococci species was revealed ( $p=0.019$ ). Diabetes mellitus has a significant higher prevalence ( $p=0.002$ ). Obese patients suffering to diabetes mellitus have a higher risk for spondylodiscitis (OR 5.5). Mortality rate was similar in both cohorts (12% NWG vs. 12.2% OG), as was the distribution of spondylodiscitis localization.

**Conclusion:** Obesity – especially combined with diabetes mellitus – and its higher proportion of *Staphylococcus aureus* infections, is a risk factor for the severe course of spondylodiscitis including higher revision rates and sepsis, especially in younger patients.

### P 93

#### Consistent postoperative recording and therapy of the germ spectrum in infections after dorsal lumbar spondylodesis for quality control – a data analysis of 599 patients

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**Introduction:** In spite of extensive avoidance strategies, wound infections in the operative treatment of degenerative diseases of the spine are a problem, especially in the dorsal approach, which is often associated with a prolonged convalescence for the patient. In addition to the common surgical treatment, the consistent recording of the spectrum of germs and the targeted antibiotic therapy play a decisive role. The aim of the present study was the analysis of the own patients with regard to the occurrence of postoperative wound infections, the detection of the germ spectrum and the determination of patient-specific risk factors.

**Methods:** The present retrospective data analysis includes 599 patients who were treated in our clinic by means of lumbar spondylodesis during the period 01/2017 to 12/2017. 49 patients developed a postoperative wound infection requiring revision. The analysis was carried out with regard to instrumentation length, infection depth and present germ spectrum. In addition, patient-dependent factors (sex, age, diabetes mellitus, cardiovascular disease, anticoagulant use, immunosuppression, obesity, previous operations) were determined.

**Results:** The total infection rate after spinal fusion in the lumbar spine was 8.1% in our patient population (26.5% short-term fusion, 73.5% multi-segmental fusion). The pathogen *Staphylococcus epidermidis* was the most frequently detected with 30.6%, followed by *Enterococcus faecalis* with 12.9%. The risk of infection increased with age (71.4% in the 60-84-year-olds and 28.6% in the 41-59-year-olds) and the ASA score. 27% of the revised patients had diabetes mellitus. 44% of the patients with infection had had previous spine surgery. The average BMI was 32 (range 20-42). With regard to gender, existing cardiovascular comorbidities, anticoagulation and immunosuppression, this study did not show a significantly increased risk for the occurrence of wound infections requiring revision.

**Conclusion:** Postoperative wound infections after dorsal lumbar spondylodesis are still a not uncommon, but still a serious complication. Especially elderly, patient with previously spine surgery, and patients with corresponding comorbidities are affected. Through consistent analysis of the spectrum of germs with consecutive antibiotic treatment in combination with equally consistent surgical therapy this complication is manageable.

### P 94

#### The surgical treatment of pyogenic spondylodiscitis using carbon fiber reinforced PEEK – a report of 70 consecutive patients

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**Introduction:** Pyogenic spondylodiscitis (PSD) might cause severe neurological deficit with high mortality rates. The ideal treatment including surgical management is still challenging and complex. Decompression and fusion using metal implants is frequently performed but yields the disadvantage of artefacts on postoperative imaging. Carbon fibre reinforced PEEK (CFRP) allows an optimal visualisation of the bone and soft tissue structures due to its radiolucency. Here the authors present their initial experience in using this implant for the treatment of PSD.

**Material:** All consecutive patients who underwent surgical management for PSD using CFRP-implants were identified. Files were reviewed with special focus on surgical technique, postoperative healing process, implant associated complication including revision surgery. Clinical outcome and postoperative MRI scans were evaluated with respect to soft tissue and neural structure identification (0-22 points) in patients with a minimum follow-up of 3 months.

**Results:** A total of 70 patients with a mean age of 70 years (range: 43-87 years) were evaluated. ACDF with cervical plating was performed in six patients, in one among those patients an additional lumbar fusion (TLIF) was performed for PSD. Posterior fixation was performed in 16 thoracic cases, in two among those cases additional corpectomy, and in six cases transforaminal thoracic interbody fusion (TTIF) was performed. TLIF was performed in 44 out of 49 lumbar procedures, in four cases lateral corpectomy was performed in addition to posterior fixation. Intraoperatively in one case the tip of the pedicle screw broke. No other implant associated complications occurred intraoperatively. Revision surgery was performed for CSF fistula in three cases, wound infection and abscess in four cases each, postoperative hematoma in one case. Nine patients died within the first three weeks postoperatively. All patients received a minimum of 6 weeks of antibiotic treatment. Revision surgery due to cervical plate loosening and cage dislocation was performed in one case. Cage dislocation with consecutive endplate destruction and screw loosening were the cause for revision surgery in three lumbar cases. The mean follow-up was 6 months (range 3-24 month) and on none of cases CRP levels and MRI scan indicated a latent infection. At follow-up, 85% of patients reported clinical success and the mean score for MRI evaluation was 19.2 points, in three patients the postoperative imaging was limited in its assessability.

**Conclusion:** Surgical management of PSD is safe using CFRP implants. No latent infection was noted and revision surgery due to implant related complication was 6%. Excellent postoperative MRI image quality allowed for optimal evaluation of soft tissue and neural structures.

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