



## Abstracts

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Berlin, Germany

## V 01

**Influencing factors on PROMs in spine surgery**

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**Background:** This prospective study investigates the influencing factors: depression, duration of symptoms, body weight and age on PROMs in spine surgery.

**Methods:** PROMs evaluating spine function (Oswestry Disability Index ODI, Core Outcome Measures Index COMI, Subjective Spine Value SSpV) and PROMs assessing health-related quality of life EQ-5D-5L, EQ-VAS and Patient Reported Outcomes Measurement Information System PROMIS-29 were collected in 160 patients pre- as well as post-operatively at 6 weeks, 3 months, 6 months and one year.

The influence of existing depression, duration of symptoms, overweight and age is investigated by multiple analysis of variance.

**Results:** Pre-existing preoperative depression does not influence PROMs assessing spinal function, (SSpV ( $p=0.645$ ), ODI ( $p=0.437$ ), COMI ( $p=0.179$ )). General health-related quality of life is impaired in the qualities of sleep, fatigue, anxiety, and depression by 0.6–2 standard deviations ( $p<0.001$ ).

For suffering less than 3 months, ODI, COMI, pain impairment and physical function showed better results postoperatively ( $p<0.05$ ). Chronic complaints showed significant impairment in overall health-related quality of life ( $p<0.05$ ).

Normal weight patients showed a faster improvement in spinal function ( $p<0.05$ ). Body weight did not affect PROMs of health-related quality of life.

Younger patients showed better results earlier than older patients for both PROMs of spine function and PROMs of health-related quality of life ( $p<0.05$ ).

**Discussion:** Health-related quality of life is affected by spinal function. Pre-existing depression does not affect spinal function or its measurement tools.

Younger and normal weight patients showed earlier convalescence. Chronic discomfort permanently impairs health-related quality of life and decreases postoperative spinal function. The negative influence of the duration of discomfort on PROMs, points to the relevance of the indication.

The results point out the special requirements of postoperative treatment in frail (elderly, overweight) patients. The findings of the study have clinical relevance for surgical education and patient information.

## V 02

**Impact of norepinephrine on human intervertebral disc cells**

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**Objectives:** Intervertebral disc degeneration (IVDD) is the most common cause of low back pain. IVDD is accompanied by invasion of blood vessels and sympathetic nerve fibers. In general, the most relevant peripheral sympathetic neurotransmitter norepinephrine (NE) exerts its effects in a concentration-dependent manner via the  $\alpha$ - and  $\beta$ -adrenoceptors (ARs). We demonstrated their expression in IVD cells earlier, however, the role of NE during the pathogenesis of IVDD has not yet been investigated. Therefore, the aim of this study was to analyze the effect of NE on IVD cells in vitro.

**Methods:** IVD samples were collected from patients undergoing a spondylodesis. Cells were isolated enzymatically and cultured in monolayer under physioxia (2% O<sub>2</sub>). IVD cells were treated with

–8 M) and high (10<sup>-6</sup> M) NE concentrations. Short-term stimulation was performed to analyze the activity of the major NE-dependent intracellular signaling pathways (ERK1/2, PKA) by immunoblotting.

After long-term stimulation for 14 days, proliferation was determined by cell counting and cell viability by lactate dehydrogenase (LDH) assay. Gene expression of structural matrix components (COL1A1, COL2A1, COL10A1, ACAN, COMP), degrading matrix metalloproteinases (MMP1, MMP2, MMP12), inflammatory cytokines (IL1B, IL6, TNF), and of the pain-related substance P (TAC1) was analyzed by qPCR.

**Results and Conclusion:** Short-term stimulation with NE resulted in activation of ERK1/2 and PKA signaling pathways with a peak between 15 and 30 minutes. After 14 days, there was a significant increase in cell number in the untreated (1.85-fold,  $p=0.049$ ), as well as in the NE-treated groups (10<sup>-8</sup> M 2.16-fold,  $p=0.049$ ; 10<sup>-6</sup> M 2.26 fold,  $p=0.044$ ) compared to day 0. The LDH assay revealed no toxic effect of NE on IVD cells. A significant decrease in MMP1 (0.12-fold,  $p=0.002$ ), MMP12 (0.18-fold,  $p=0.005$ ) as well as TAC1 (0.06-fold,  $p<0.001$ ) expression was detected in the untreated groups after 14 days compared to day 0. The long-term treatment with both NE concentrations led to significantly decreased expression of COL10A1 (10<sup>-8</sup> M 0.38-fold,  $p=0.006$ ; 10<sup>-6</sup> M 0.47-fold,  $p=0.004$ ) after 14 days. In addition, the stimulation with 10<sup>-6</sup> M NE caused a significantly decreased MMP2 expression (0.54-fold,  $p=0.03$ ), while 10<sup>-6</sup> M NE significantly increased TAC1 expression (4.34-fold,  $p=0.003$ ) compared to the untreated group at day 14. The genes ACAN, COL1A1, COL2, COMP, IL1B, IL6, MMP1, MMP12, and TNF were unaffected by long-term stimulation with NE.

We demonstrated that human IVD cells were able to respond to NE by ERK1/2 and PKA phosphorylation. Moreover, our results suggest that NE might play a complex role during IVDD by inhibiting chondrocyte hypertrophy (decreased COL10A1 expression) and matrix degradation (decreased MMP2 expression) but increasing pain sensation (increased TAC1 expression)

## V 03

**Effect of age and lumbar spinal stenosis on static and dynamic sagittal spinal balance – results of a pilot study**

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**Introduction:** Sagittal spinal balance (SSB) depends on age and disease<sup>1,2</sup> and can be described by global (e.g., spine inclination (SI)) or local (e.g., thoracic kyphosis (TK) and lumbar lordosis (LL)) parameters. Most commonly, SSB is assessed using radiography with the patient in a standardized upright standing position. 3D motion analysis using retroreflective markers and infrared cameras allows to record comparable SSB parameters dynamically. There is evidence that SSB differs between patients with symptomatic lumbar spinal stenosis (sLSS) and healthy individuals<sup>3</sup>. The aim of this study was to investigate whether SSB differs between patients with sLSS, elderly healthy and young healthy subjects during standing and walking.

**Material/Method:** In 10 patients with sLSS (5M/5F; age, 70±10 years; body mass index (BMI), 29±5 kg/m<sup>2</sup>), 10 elderly healthy persons (5M/5F; 65±5 years; 25±6 kg/m<sup>2</sup>), and 10 young healthy persons (5M/5F; 26±2 years; 22±2 kg/m<sup>2</sup>), SSB was determined in an upright standing position and during gait using 18 reflective markers on the spinal spinous processes. The curvature of the thoracic and lumbar spine was calculated from the coordinates of the markers using a 3rd order polynomial<sup>2</sup>. Subsequently, the angles between T3 and T12 (TK), L1 and S1 (LL), and between the

line connecting C7 and S1 and the vertical (SI) were calculated (Fig.1). Dynamic SSB was calculated during the left midstance phase of gait. The influence of group and movement on SSB was examined by two-way ANOVA with repeated measures ( $P < 0.05$ ).

**Results:** SI was significantly greater during walking than during standing across all groups (Fig. 2;  $P < 0.001$ ). Moreover, SI was greater in patients and elderly healthy than in young healthy persons (Fig 2; all  $P < 0.001$ ). The difference between static and dynamic SI was greater in patients and elderly healthy than in young healthy persons (interaction:  $P = 0.015$ ). There was a significant group effect for TK ( $P = 0.012$ ) with higher values in elderly healthy than in young healthy persons. There were no significant differences in SSB between patients with sLSS and elderly healthy subjects.

**Discussion:** The studied SSB parameters seem to be mainly dependent on age and task, but not on sLSS. Because SI was greater during walking than standing in all groups, it is reasonable to assume that increased SI is a component of human forward motion. This mechanism appears to become more important with increasing age. The extent to which this is might be influenced by fatigue or worsening symptoms in patients with sLSS requires further investigation. Future studies should also include additional SSB parameters describing pelvic alignment.

1 Zappala et al. 2021 *J Orthop Surg Res*

2 Ignasiak et al. 2017 *Hum Mov Sci*

3 Farrokhi et al. 2016 *Clin Neurol Neurosurg*

Fig. 1

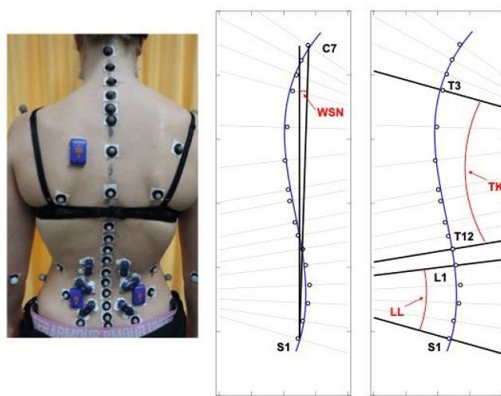


Fig.1: Markerplatzierung auf den Dornfortsätzen (links) und Definition der WS-Statik Parameter WSN (Mitte), TK und LL (rechts)

Fig. 2

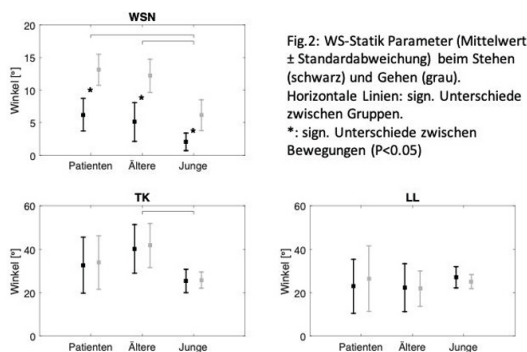


Fig.2: WS-Statik Parameter (Mittelwert  $\pm$  Standardabweichung) beim Stehen (schwarz) und Gehen (grau). Horizontale Linien: sign. Unterschiede zwischen Gruppen. \*: sign. Unterschiede zwischen Bewegungen ( $P < 0.05$ )

V 04

**Performance of artificial intelligence-based algorithms to predict prolonged length of stay after lumbar decompression surgery**

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**Background:** Decompression of the lumbar spine is one of the most common procedures performed in spine surgery. Hospital length of stay (LOS) is a clinically relevant metric used to assess surgical success, patient outcomes, and socioeconomic impact. This study aimed to investigate a variety of machine learning and deep learning algorithms to reliably predict whether a patient undergoing decompression of lumbar spinal stenosis will experience a prolonged LOS.

**Methods:** Patients undergoing treatment for lumbar spinal stenosis with microsurgical or full-endoscopic decompression were selected within this retrospective monocentric cohort study. Prolonged LOS was defined as a LOS greater than or equal to the 75th percentile of the cohort (normal versus prolonged stay; binary classification task). Unsupervised learning with k-means clustering was used to find clusters in the data. Hospital stay classes were predicted with logistic regression, RandomForest classifier, stochastic gradient descent (SGD) classifier, KNearestNeighbors, Decision Tree classifier, Gaussian Naive Bayes (GaussianNB), support vector machines (SVM), a custom-made convolutional neural network (CNN), multilayer perceptron artificial neural network (MLP), and radial basis function neural network (RBNN) in Python. Prediction accuracy and area under the curve (AUC) were calculated. Feature importance analysis was utilized to find the most important predictors. Further, we developed a decision tree based on the Chi-square automatic interaction detection (CHAID) algorithm to investigate cut-offs of predictors for clinical decision-making.

**Results:** 236 patients and 14 feature variables were included. K-means clustering clustered data into two clusters distinguishing the data well into two patient risk characteristic groups. The algorithms reached AUCs between 67.5% and 87.3% for the classification of LOS classes. Feature importance analysis of deep learning algorithms indicated that operation time was the most important feature in predicting LOS. A decision tree based on CHAID could predict 84.7% of the cases.

**Conclusions:** Machine learning and deep learning algorithms can predict if patients will experience an increased LOS following lumbar decompression surgery. Therefore, medical resources can be more appropriately allocated to patients who are at risk of prolonged LOS. Future prospective studies are warranted to validate the presented algorithms.

V 05

**Prospective randomized controlled study of lumbar facet replacement vs. TLIF fusion for degenerative spondylolisthesis – two year outcomes**

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**Introduction:** Posterior lumbar arthroplasty with facet replacement represents a potential motion-preserving alternative to standard lumbar spinal fusion in the treatment of degenerative spondylolisthesis with stenosis. There is, however, a lack of long-term Level I evidence demonstrating the safety and efficacy of a mobile implant that replaces the function of the facet joints.

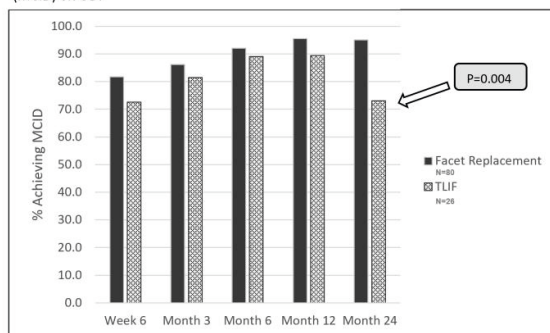
**Material/Method:** This is an interim analysis from a prospective, randomized, controlled FDA clinical trial (G160168) comparing a facet replacement System (TOPS) vs Fusion (TLIF) in the treatment of Grade I degenerative spondylolisthesis and stenosis. The primary endpoint was the percentage of subjects achieving overall clinical success defined as at least a 15-point reduction in the Oswestry Disability Index (ODI) and no clinically meaningful supplemental surgical intervention. Safety was assessed as the incidence of all-cause surgical intervention after the index surgery. The maintenance of motion at the treated level was also assessed among subjects that underwent facet replacement. A minimum of 24 months follow up was required for inclusion in this study.

**Results:** At the time of this analysis 249 patients have been enrolled (TOPS =170; TLIF= 79) and a total of 106 patients were evaluable at 24 months (TOPS=80, TLIF=26). At 24 months, the percentage of subjects reporting overall clinical success showed a significant difference (p-value=0.013) between TOPS (95.0%) and TLIF (76.9%) (Fig. 1). Among all 249 subjects that were enrolled the rate of surgical reintervention for TOPS was 5.9% and for TLIF group was 8.8%. Among subjects that underwent facet replacement, radiographic analysis demonstrated that the treated segment remained stable with preservation of motion. The change in angular motion from pre-op to Month 24 on flexion-extension and left/right lateral bending was 0.01 degrees and 0.50 degrees respectively. The change in translation from pre-op to Month 24 on flexion/extension was -0.16 mm (Fig.2).

**Discussion:** The preliminary results for the TOPS facet replacement system demonstrate better long-term clinical outcomes with re-operation rates which are consistent with literature for surgical treatments to address spondylolisthesis with stenosis. The TOPS stabilizes the treated segment following decompression while also maintaining motion. Lumbar facet arthroplasty appears to be a viable option for treatment of degenerative spondylolisthesis in lieu of fusion. Continued enrollment and further analysis of the long-term follow-up is required to validate these early findings and evaluate differences between facet arthroplasty and fusion.

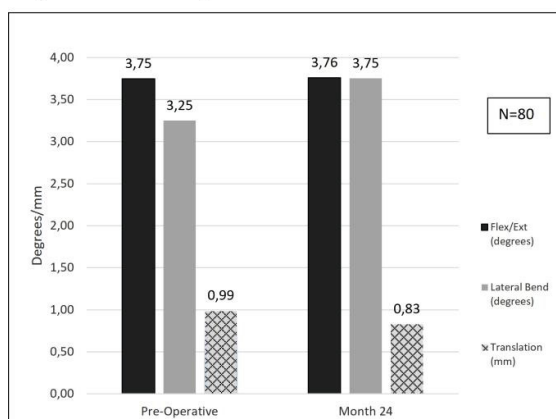
**Fig. 1**

Figure 1: % of subjects reporting  $\geq 15$  point improvement (MCID) on ODI



**Fig. 2**

Figure 2: ROM Among TOPS at Pre-OP and at 24 Months



#### V 06

##### Analysing the outcome for gait and pain following TLIF versus microsurgical decompression in spinal claudication

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**Introduction:** Spinal claudication (SC) is typical for lumbar spinal canal stenosis (SCS). To date, there is no consensus with respect to the ideal method (microsurgical decompression (MSD) or transforaminal lumbar interbody fusion (TLIF) of surgical treatment for this entity. The aim of the study is, to analyse, if there is a significant difference between both surgical options with respect to gait and pain for patients having SC in the presence of monosegmental SCS.

**Material/ Methods:** Prospective study, approved by the local ethic committee. Patients included: CS by monosegmental lumbar compression, ASA < 3, no gait disturbance except by CS. Decision for MCD or TLIF is based on clinical judgement including patients wish. Statistics performed by an independent researcher using current version of SPSS. ANOVA, T-Test. Significance assumed for  $p < 0.05$ . Analysing the outcome via 1. treadmill test for 15 minutes, no inclination. 2. VAS score, both performed preop as well as 3 and 6 months postop. We also looked at surgical time and intraop blood loss.

**Results:** 18 patients following MSD, 21 patients following TLIF. We found a significant improvement for gait within both groups after 6 months. MSD: 540 m to 838 m, ( $p < 0,001$ ), TLIF: 560 m to 773 m, ( $p = 0,001$ ). Moreover, MSD patients had significant improvement after 3 months, 540 m to 776 m,  $p = 0,002$ . Also, TLIF patients were improved after 3 months, however, this difference was not significant (560 m to 681 m,  $p = 0,71$ ). No difference was found between both groups for neither gait nor pain at any time. There were significant differences of MSD versus TLIF for blood loss (MSD: 88 ml, TLIF 722 ml, ( $p < 0,001$ ) and surgical time (MSD 63 min, TLIF 192 min,  $p < 0,001$ ).

**Discussion:** MSD and TLIF are both appropriate procedures for surgical treatment of CS with respect to pain and gait. However, blood loss and surgical time are significantly lower in MSD. Thus, MSD may be more appropriate in elderly patients.

#### V 07

##### "Lateral-PLIF", modified PLIF technique for spinal arthrodesis – concept, technique, results, complications and outcomes

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**Purpose:** Lumbar interbody fusion surgery is an effective treatment option to treat degenerative conditions in the lumbar spine. There is still no consensus on the best operative technique, based on published inconsistent outcomes and no recent studies. We present a variant of the PLIF technique, lateral-PLIF, from a prospective consecutive series of patients.

**Methods:** Patients underwent consecutively a single/double level Lateral-PLIF were prospectively recruited from January to December 2017 for the primary diagnosis of isthmic or degenerative spondylolisthesis, lumbar spinal stenosis, severe degenerative disc disease, and/or recurrent disc herniation. Revision cases were not excluded.

Lateral PLIF consist of a modified PLIF technique with preservation of both lamina, bilateral foraminal opening and more lateral insertion of the cages through the supra-recessal space, between the central canal and the foramen.

Patients were asked to complete prospectively pre- and postoperative questionnaires at 4 months, 1- and 2-years assessing pain and functional scores. Phone interviews provide treatment satisfaction rate at 4 years. Data related to the surgical procedure and post-operative complications were also collected. Radiological follow up findings (fusion and lumbar lordosis) were assessed at 1-year follow up visit based on X-rays and CT-scan.

**Results:** A total of 104 patients were consecutively included in the study. Patients were  $57.8 \pm 10.5$  years old and presented with

mechanical low back pain (104, 100%), radicular pain (97, 93.2%), and motor weakness (23, 22.1%).

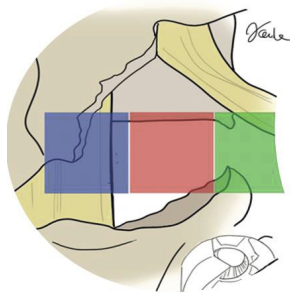
Estimated operative time was  $155.8 \pm 39.7$  min for single level,  $172.5 \pm 47.1$  min for double level. Average estimated blood loss for single level was  $480 \pm 405.9$  ml,  $700 \pm 461.8$  ml for double level.

We found high incidence of fusion rate (95%). A statistically significant improvement of function was noted (decreased of ODI from  $49.4 \pm 12.5$  [22-82] to  $29.2 \pm 17.1$  [4-62] at 1-year,  $p < 0.001$ , and of Roland-Morris score from  $14.9 \pm 4.8$  [3-24] to  $8.4 \pm 6.4$  [0-19] at 1-year,  $p < 0.001$ ). Walking distance increased from  $812\text{m} \pm 543\text{m}$ , to  $3443\text{m} \pm 712\text{m}$  ( $p < 0.001$ ).

Complication included 1 permanent nerve root dysfunction (0.9%) and 2 pedicle screws loosening (1.9%). 5 (4.8%) cases of infections/wound dehiscence, 2 (1.9%) malposition of pedicle screws, 1 (0.9%) iatrogenic arterial injury during discectomy. No CSF fistula, epidural hematoma or migration of cage were observed.

**Conclusion:** Our results suggest that Lateral-PLIF is a safe and efficient technique with extensive applicability to achieve lumbar fusion while restoring an appropriate disc height and a correct lordosis. Complications rates associated with the traditional PLIF technique were lower in our series compared to the rates usually reported in the literature. Although further comparative studies will be necessary to validate the final outcomes, surgeons might consider this technique before using a routine standard lumbar fusion approach.

Fig. 2



V 08

The mechanical effect of outrigger rods and rod stiffness on quad rod constructs in long spinal instrumentation – a finite element perspective

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**Introduction:** Rod fractures can occur in long spinal fusion patients due to the high load exerted on the instrumentation. Various clinical cases with quad rod techniques with rods of different diameters and materials have been previously described and shown to improve survival of long spinal constructs. Nevertheless, there is no deeper mechanical understanding to which extent the quad rod technique reduces the stresses in the primary rods compared to the dual rod technique and if and how outrigger rod stiffness influences the construct. The purpose of this biomechanical study was to determine which construct type and rod combination to choose to optimally reduce the rod stresses in primary rods of long spinal fusion constructs in flexion and axial rotation.

**Materials and Methods:** 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. Subsequently, two different construct types of long spinal fusion L1 to ilium were modeled: a dual rod baseline construct and a quad

rod construct with long outrigger rods and low connector density (Figure 1A, lateral and posterior view). The rods were modeled with Ti6Al4V (Ti) and CoCr material properties and with diameters of Ø5.5 and Ø6 mm, leading to twenty different rod combinations. All models had bilateral facetectomies and ALIF cages placed in segments L4-L5-S1. They were subjected to moments of 7.5 Nm in flexion and axial rotation. For both load cases, the highest stresses in the primary rods of the quad rod constructs were evaluated and compared to those of the corresponding dual rod constructs.

**Results:** Exemplarily for the Ø5.5 mm Ti primary rods and flexion, the contour plot of Mises stress is shown in Figure 1 B-F with magnitude and location of the maximum tensile stress: dual rod (B), quad rod with outrigger rod of Ø5.5 mm Ti (C), Ø6 mm Ti (D), Ø5.5 mm CoCr (E) and Ø6 mm CoCr (F). For all primary rod types, the quad rod construct with the lowest outrigger rod stiffness (Ø5.5 mm Ti) always had lower primary rod stresses than the corresponding dual rod construct and can therefore safely be chosen by default (Table 1). Taking flexion and axial rotation into account, the optimal rod combination can be found in Table 1 for any given primary rod stiffness.

**Discussion:** Based on our FE model, quad rod constructs with low outrigger rod stiffness typically showed low stresses in the primary rods of long spinal fusion constructs under flexion and axial rotation and always generated primary rod stresses lower than dual rod constructs. A table to choose the optimal outrigger rod for any given primary rod was provided. Quad rod constructs with a careful selection of rod combination are best suited to limit the clinical rod fracture rate.

Fig. 1

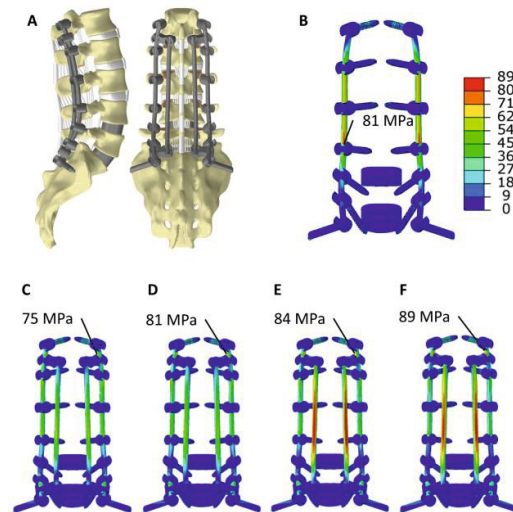


Fig. 2

Load case	Primary rod		Outrigger rod in order of increasing stiffness				
			None	Ti		CoCr	
				Ø 5.5	Ø 6	Ø 5.5	Ø 6
Flexion	Ti	Ø 5.5	0	-8	0	+4	+10
		Ø 6	0	-22	-16	-13	-7
	CoCr	Ø 5.5	0	-21	-24	-25	-20
		Ø 6	0	-22	-25	-28	-31
Axial Rotation	Ti	Ø 5.5	0	-11	-3	0	+5
		Ø 6	0	-15	-8	-5	-1
	CoCr	Ø 5.5	0	-20	-18	-15	-12
		Ø 6	0	-21	-25	-28	-25

Table 1: % change of primary rod stress vs. corresponding dual rod

V 09

**How do you treat lumbar disc herniations in order to prevent them from reherniations?**

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**Introduction:** Clinical studies have discussed the outcome of different surgical treatments after lumbar disc herniation. While in one study partial nucleotomy was superior to sequestrectomy in terms of reherniation risk (Carragee 2006), another paper showed the opposite result (Thomé 2005). In this in vitro study, this complex issue was elucidated using a standardised in vitro model to investigate lumbar disc herniations.

**Material/method:** First, a standardised disc herniation was provoked in 6 lumbar healthy motion segments (L2/3, L3/4, L4/5, L5/S1; Pfirrmann 1-2) from 4 human donors (age: 19-53 years; sex: 3 m:1 n/a) by placing an annulus defect of Ø 4 mm and then dynamically loading the segments with a new physiological loading protocol simulating activities such as box lifting (Zengerle 2021). The segments were treated with the different surgical techniques and loaded again with the described protocol, regardless of whether a reherniation occurred or not. First, a sequestrectomy was performed, then an anulotomy, in which the remaining nucleus material within the defect was removed, and finally a partial nucleotomy. Between all test steps, disc height, range of motion (ROM) and intradiscal pressure (IDP) were measured in flexion-extension, lateral bending and axial rotation, and were statistically analysed in a Friedman test with Bonferroni post hoc correction ( $\alpha \leq 0.05$ ).

**Results:** In all specimens, physiological loading resulted in a disc herniation through the annulus defect. No reherniation occurred as a result of sequestrectomy, whereas reherniations were observed in one disc after anulotomy and in two discs after partial nucleotomy (Fig. 1). The partial nucleotomy, in which significantly more nucleus material was removed: 0.38 g (0.27 g – 0.67 g), resulted in a significant increase in ROM of about 1° ( $p = 0.044$ ) and a decrease in IDP of 0.14 MPa ( $p = 0.035$ ), but only in lateral bending (Fig. 1). Disc height decreased only after sequestrectomy, while ROM and IDP did not change (Fig. 1).

**Discussion:** This study was able to investigate the treatment success of lumbar disc herniations by different surgical procedures with regard to the risk of reherniations under realistic conditions. The results of this study could support the clinical findings that the risk of reherniations after sequestrectomy is lower than after partial nucleotomy.

**Fig. 1**

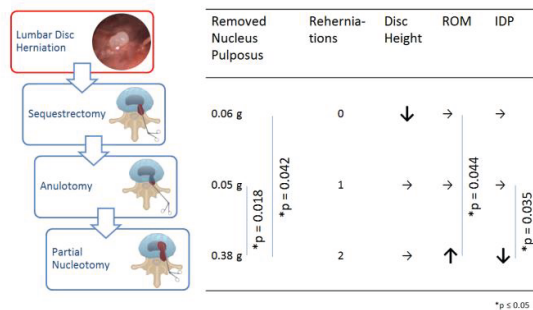


Fig. 1: Provoked reherniations and effect of the removal of nucleus pulposus on the biomechanical parameters disc height, range of motion (ROM) and intradiscal pressure (IDP) after treating the index lumbar disc herniation with a sequestrectomy, anulotomy and partial nucleotomy, \*  $p \leq 0.05$ .

V 10

**Risk factors for in-hospital mortality in pyogenic spondylodisctis based on a nationwide analysis of the epidemiology, concomitant diagnoses and pathogens in 9,753 cases**

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**Introduction:** Pyogenic spondylodisctis may be associated with high morbidity and mortality rates. The aim of this register study was to provide a comprehensive overview of associated diseases and pathogens and to analyze potential risk factors for in-hospital mortality.

**Methods:** The Institute for Hospital Remuneration Systems (InEK GmbH) was used as a nationwide data source to analyze all hospitalized cases of patients with pyogenic spondylodisctis in 2020. ICD-10 codes "M46.2-," "M46.3-," and "M46.4-" were queried to identify these cases. InEK GmbH provides detailed data on the number and epidemiology of spondylodisctis cases, all concomitant diagnoses, and coded pathogens. From the datasets of patients with and without documented in-hospital deaths the Odds ratios (OR) with 95% Confidence Interval (CI) for several factors were calculated.

**Results:** In total 150,958 concomitant diagnoses were documented per 9,753 cases in 2020. The most common concomitant diagnoses were arterial hypertension (55.6%), hypokalemia (34.9%) and anemia due to bleeding (20.9%) followed by spinal abscess (intra- and extradural, 16.5%) as most documented (Tab. 1). Pathogens were coded for as concomitant diagnoses in 7589 cases (77.8%). In most cases "other/unspecified staphylococci" were documented (27.1%), followed by *Escherichia coli* and other Enterobacterales (22.4%), *Staphylococcus aureus* (19.4%) and Streptococci (17.8%). An elevated in-hospital mortality was significantly associated with the patient-age: 65 years and older: OR=1.28 (95% CI 1.14 to 1.44), 75 years or older: OR=1.57 (95% CI 1.39 to 1.78), 80 years or older: OR=1.81 (95% CI 1.58 to 2.08; each  $p < 0.01$ ). Non-modifiable concomitant diagnoses (Figure 1A), associated with in-hospital mortality were congestive heart failure (OR=2.8; 95% CI 2.45 to 3.20), type II diabetes with complications (OR=1.86; 95% CI 1.46 to 2.38) and chronic kidney disease (OR=1.83; 95% CI 1.57 to 2.13; each  $p < 0.01$ ). Regarding modifiable factors (Figure 1B), the highest risks for the in-hospital mortality was associated with acute liver failure (OR=42.41; 95% CI 23.47 to 76.62;  $p < 0.01$ ). Further, stadium III acute kidney failure (OR=9.81; 95% CI 7.96 to 12.08) and sepsis (OR=5.94; 95% CI 5.02 to 7.03; each  $p < 0.01$ ) were associated with in-hospital mortality.

**Discussion:** Patients with chronic or acute organ disease and infectious complications are at increased risk for in-hospital mortality. Efforts should be made to identify these high-risk patients early and initiate targeted treatment.

Table 1: Most common concomitant diagnoses in spondylodisctis cases in 2020.

Figure 1: Odds ratios for in-hospital mortality in cases with non-modifiable (A) and modifiable factors (B). \* indicates  $p < 0.05$ .

**Fig. 1**

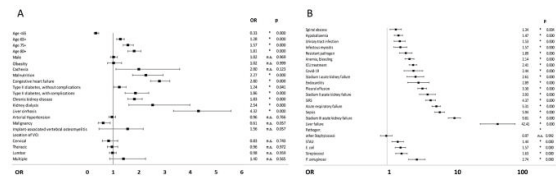


Table 1: Most common concomitant diagnoses in spondylodiscitis cases in 2020.

Tab. 1

	Concomitant diagnosis	ICD-10 code	[n]	Percentage of all cases
Non-modifiable	Arterial Hypertension	I10.-	5,424	55.6%
	Type II diabetes	E11.-	2,819	28.9%
	Congestive heart failure	I50.-	2,522	25.9%
	Atrial fibrillation	I48.-	2,365	24.3%
	Chronic kidney disease	N18.1-; N19	2,325	23.8%
	Coronary arterial disease	I25.0; I25.10-19	1,655	17.0%
	Hypothyreosis	E03.8; -9	1,264	13.0%
	Obesity	E66.0-99	997	10.2%
	Malignancy	C01; C10.-C97	736	7.6%
	Malnutrition	E43-E46	559	5.7%
	Implant-associated vertebral osteomyelitis	T81.4	431	4.4%
	Liver cirrhosis	K74.6; 70-72	365	3.7%
	Dialysis	Z99.2	154	1.6%
	Cachexia	R64	107	1.1%
	Modifiable	Hypokalemia	E87.6	3,408
Anemia, bleeding		D62	2,039	20.9%
Spinal abscess		G06.1; -2	1,612	16.5%
Urinal tract infection		N39.0	1,595	16.4%
Pleural infusion		J90; J91	1,576	16.2%
Acute respiratory insufficiency		J96.01; J96.00	1,441	14.8%
Acute kidney failure		N17.0-; N17.81-3, -9; -; N17.91-3, -9	1,185	12.2%
Pneumonia		J12.8-J18.9	1,066	10.9%
Infectious myositis		M60.05	1,010	10.4%
SIRS		R65.0-3	980	10.1%
Sepsis		A40.1-8; A41.1-9	854	8.8%
Covid-19		U07.1, 2	332	3.4%
Endocarditis		I33.0	222	2.3%
Acute liver failure		K72.0	59	0.6%

## V 11

## Early- and late-mortality in vertebral osteomyelitis

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**Objective:** Vertebral osteomyelitis is a severe clinical entity associated with high mortality rates, especially within the first year after diagnosis. The aim of this study was to identify and compare predictive factors influencing early- and late- mortality in patients with conservative and surgically treated VO.

**Methods:** We conducted a prospective monocentric study including VO patients from 2008 to 2020 to determine early- (=death within 30 days after diagnosis) and late- (=death within day 31- day 365 after diagnosis) mortality rates. Additionally, multivariable analysis was performed to analyze predictive risk factors for mortality.

**Results:** In 323 evaluable patients early-mortality occurred in 17 (5%) and late-mortality in 61 (19%) patients. Multivariable analysis revealed chronic kidney disease (OR:9.073, 95%CI 4.186-19.666;  $p < 0.001$ ) and *Staphylococcus aureus* (OR:6.081, 95%CI 2.491-14.844;  $p < 0.001$ ) as independent risk factors for early-mortality whereas ASA score >2 (HR:5.237, 95%CI 2.588-10.597;  $p < 0.001$ ), age >70 years (HR:2.417, 95%CI 1.575-3.708;  $p < 0.001$ ), chronic kidney disease (HR:1.950, 95%CI 1.254-3.032;  $p = 0.003$ ) and bacteremia (HR:1.829, 95%CI 1.238-2.701;  $p = 0.002$ ) were identified as independent risk factors for late-mortality.

**Conclusion:** Almost one out of four VO patients dies within the first year after diagnosis. Therefore, special attention should be paid to patients with associated risk factors, not only during hospitalization, but especially during the first year. Since renal failure in particular could be identified as a main risk factor, special caution is required when applying potentially nephrotoxic substances (e.g., analgesics or antibiotics) in order to avoid further renal damage.

## V 12

## Epidemiologic trends in pyogenic spondylodiscitis in Germany – a cross-sectional analysis of 95,075 hospitalized cases from 2010 through 2020

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**Introduction:** Pyogenic spondylodiscitis is considered the most common manifestation of hematogenous osteomyelitis in adult patients. However, reports on the epidemiology of spondylodiscitis remain heterogeneous. The aim of this cross-sectional study was to determine the evolution of nationwide incidence rates of spondylodiscitis as a function of age, sex, and anatomic location for Germany between 2010 and 2020.

**Methods:** Data consisting of annual codes of the tenth version of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) diagnosis codes from German medical institutions between 2010 through 2020 was provided by the Federal Statistical Office of Germany (Destatis). Further, number of in-hospital deaths, length of hospitalization and treatment on an intensive care unit (ICU) was provided. Total number of pyogenic spondylodiscitis cases were quantified using the ICD-10 Codes "M46.2-", "M46.3-", and "M46.4-" and analyzed as a function of gender and age in 10-year increments for patients older than 20 years from 2010 through 2020, respectively. Incidence rates were calculated based on the data of Germany's historical population aged 20 years or older provided by Destatis.

**Results:** A total of 95,075 inpatient cases of pyogenic spondylodiscitis were registered and evaluated between 2010 and 2020. The incidence rate increased by 41.6% to 14.4 per 100,000 population during this period. In 2020, the male-to-female ratio was 1.5. In 62.2% of documented cases, patients were 70 years or older (34.8% of all cases in 2020, Figure 1). The lumbar spine (56.2%) and thoracic spine (18.3%) were most commonly affected, followed by the cervical spine (6.7% of all cases). Spondylodiscitis with multiple foci was documented in 2.2% of cases (Figure 2). The in-hospital mortality rate was 6.5% in 2020. In-hospital deaths doubled from  $n = 314$  (4.6%) in 2010 to  $n = 631$  in 2020 (+1.9%; Figure 3). ICU treatment was documented in 28.3% of all cases in 2020. Spondylodiscitis cases accounted for a total of 217,416 days stay in hospital in 2020, compared with 173,581 days in 2010, resulting in a mean length of stay of 22.8 days per case, compared with 25.1 days in 2010 (-9.2%).

**Discussion:** The current study highlights that pyogenic spondylodiscitis is a potentially life-threatening disease with an increasing incidence rate.

Figure 1: Age and gender distribution of spondylodiscitis cases in 2020.

Figure 2: Distribution of spondylodiscitis cases in 2020 by anatomical location.

Fig. 1

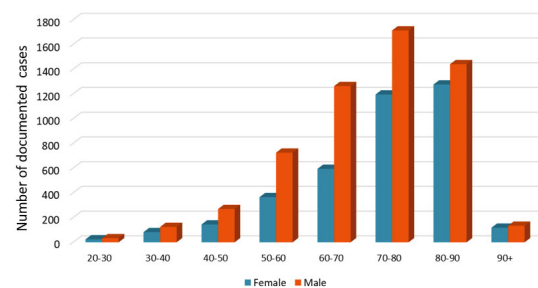
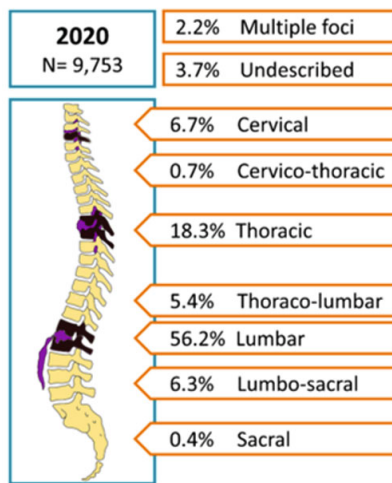


Fig. 2



## V 13

**Attachment of *Staphylococcus aureus* on implants used in operative treatment of destructive spondylodiscitis**

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**Introduction:** Spondylodiscitis is becoming a more common problem in spinal surgery due to rising numbers of elderly patients. In case of bone destruction, the infected tissue is often removed. Reconstruction can be obtained by inserting an implant. A survey conducted among German speaking spinal surgeons comes to no conclusion as to which material should preferably be used. The aim of this study is to find out whether some materials of spinal implants are more or less prone to bacterial attachment.

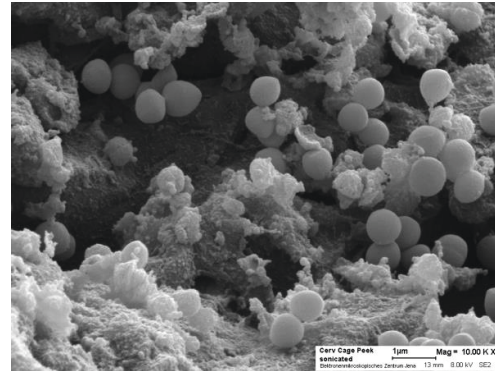
**Materials and Methods:** Eight cages of each PEEK, PEEK with Titan coating (PEEK-Ti), Titan, Polyetherketoneketone (PEKK), Tantalum and bone cement have been incubated with 20% human plasma for 24h. Subsequently, three cages of each material have been incubated with *S. aureus* for 24h and three for 48h. Two implants per material have been used for negative control. The biofilm was then removed by sonication. The attained fluid was used to make a 1:10 serial dilution which have been plated on Mueller-Hinton agar plates. After 24h the CFUs (Colony Forming Units) have been counted. Furthermore, the biofilm has been analyzed by scanning electron microscopy.

**Results:** The CFUs have been compared directly and in relation to the cages surface area. The surface area of the implants was PEEK 557mm<sup>2</sup>, PEEK-Ti 472mm<sup>2</sup>, Titan 985mm<sup>2</sup>, PEKK 594mm<sup>2</sup>, Tantalum 706mm<sup>2</sup>, bone cement 123mm<sup>2</sup>. The mean CFU count after 24h (PEEK 6.77x10<sup>7</sup>, PEEK-Ti 2.02x10<sup>8</sup>, Titan 1.57x10<sup>8</sup>, PEKK 2.63x10<sup>8</sup>, Tantalum 1.73x10<sup>8</sup>, bone cement 3.33x10<sup>8</sup>) and after 48h (PEEK 1.07x10<sup>8</sup>, PEEK-Ti 2.61x10<sup>8</sup>, Titan 1.99x10<sup>8</sup>, PEKK 2.88x10<sup>8</sup>, Tantalum 3.23x10<sup>8</sup>, bone cement 5.05x10<sup>8</sup>) was calculated. Likewise, the mean CFU count per mm<sup>2</sup> surface area after 24h (PEEK 1.22x10<sup>5</sup>, PEEK-Ti 4.27x10<sup>5</sup>, Titan 1.59x10<sup>5</sup>, PEKK 4.42x10<sup>5</sup>, Tantalum 2.46x10<sup>5</sup>, bone cement 2.71x10<sup>6</sup>) and after 48h (PEEK 1.92x10<sup>5</sup>, PEEK-Ti 5.53x10<sup>5</sup>, Titan 2.02x10<sup>5</sup>, PEKK 4.85x10<sup>5</sup>, Tantalum 4.58x10<sup>5</sup>, bone cement 4.10x10<sup>6</sup>) was calculated. No statistical significance has been found between the different materials ( $p > 0.05$ ). All materials seem to be similarly prone to biofilm formation. The electron microscopic pictures show the attachment of the bacteria, as well as production of extracellular polymeric substances (EPS) as a sign for beginning biofilm formation (Fig. 1).

**Discussion:** There is no difference between the examined materials regarding bacterial attachment after 24h and 48h. In further studies, we want to find out whether differences become apparent after longer incubation.

Fig. 1 – Electron microscopic picture showing the surface of a PEEK cage with human plasma coating after incubation with *S. aureus* for 24h

Fig. 1



## V 14

**Does pathogen detection in vertebral osteomyelitis affect quality of life?**

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**Introduction:** (background, relevance and research question)

The therapy of spondylodiscitis or vertebral osteomyelitis (VO) usually consists of anti-infective and surgical therapy. The anti-infective treatment should be adjusted in accordance with the results of the blood culture analysis. If the culture turns out to be negative, the continuation of the empiric antibiotic therapy is recommended. The aim of this work is to compare the quality of life one year after surgery between the patients with and without blood culture pathogen detection.

**Material/method:** (patient collective, method, statistical procedures)

All patients with VO were enrolled prospectively and monocentrically as part of the DWG registry. ODI and COMI scores were collected preoperatively (t0) and after 12 months (t1). Demographic data were also collected. All patients were treated surgically using interbody fusion. If a pathogen could be detected (group 1), targeted antibiotic therapy was administered. In case of culture-negative VO (group 2), empirical intravenous treatment with flucloxacillin and ceftriaxone was given initially, followed by oral treatment with clindamycin and ciprofloxacin. In both groups the duration of antibiotic treatment lasted at least two weeks intravenously and four weeks orally.

**Results:** (Results with data and statistics)

Of 133 included patients, pathogens could be detected in 100 cases, but were not found in the remaining 33 patients. The distribution of age, sex, ASA, BMI, affected segment, or length of stay did not differ between the two groups. Group 1 had a significantly higher incidence of epidural abscesses ( $p=0.006$ ). One patient in group 1 and 19 patients in group 2 underwent antibiotic treatment preoperatively ( $p<0.001$ ). A significant improvement of ODI and COMI scores from t0 to t1 was observed in both groups ( $p<0.001$ ). ODI and COMI scores were not significantly different between groups at any time point ( $p>0.05$ ).

**Discussion:** (significance of the work presented and conclusion)

Pathogen detection in VO has no impact on the quality of life according to this study. If a pathogen can be detected, targeted antibiotic therapy is indicated. In cases of a negative culture, an



empiric antibiotic regimen can still successfully complement surgical therapy. The higher number of epidural abscesses in group 1 suggests a higher virulence of the underlying pathogens. Despite established treatment algorithms, pathogen detection fails in 10% of treated patients in this group without an identifiable cause.

#### V 15

##### What are the differences in conservative versus surgical treatment of vertebral osteomyelitis? A propensity-matched analysis

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**Objective:** Vertebral Osteomyelitis (VO) is a severe clinical condition with a rising incidence in the past few years. Most patients are treated conservatively, whereas 20–40% of affected patients undergo surgery. Nevertheless, the optimal treatment is not always clearly defined. Our aim was to demonstrate differences between surgically and conservatively treated VO patients and to determine possible factors influencing relapse rate and 1-year-mortality depending on the therapy performed (conservative vs. surgical treatment).

**Material/Methods:** Between 2008 and 2020 relevant clinical data of VO patients were prospectively collected and extracted from the former European "Spine Tango" now Deutsches Wirbelsäulen Gesellschaft (DWG) registry. The decision between surgical and conservative treatment was determined for each patient on an individual basis and surgical treatment was performed according to the individual vertebral destruction. A 1:1 propensity score matching was performed to exclude potential confounders between groups. Univariate and multivariable analyses were performed to identify potential risk factors for relapse.

**Results:** 42 patients (11.8%) were treated conservatively and 313 patients (88.2%) underwent surgery for VO. Patients treated surgically had a higher ASA score (ASA score > 2: 69.0% vs. 47.5%;  $p=0.007$ ) and were diagnosed more frequently with VO of the thoracic spine (30.4% vs. 11.9%;  $p=0.025$ ). Conservatively treated patients had a higher incidence of infective endocarditis (14.3% vs. 4.2%;  $p=0.018$ ). During follow-up, conservatively treated patients had an almost three times higher relapse rate (16.7% vs. 5.4%;  $p=0.017$ ).

After propensity matching, the groups were comparable in terms of preoperative characteristics, clinical presentation, and microbiologic findings. However, after matching, the conservatively compared with surgically treated patients showed a nearly 7-fold higher 1-year mortality with 25.0% vs. 3.7% ( $p=0.018$ ).

Multivariable analysis revealed the following factors as independent risk factors for the development of relapse: conservative treatment, drug abuse and detection of coagulase-negative staphylococci (CoNS).

**Discussion:** It remains unclear which aspects influence treatment decision in VO but conservatively treated patients show an increased rate of relapse. Because patients continue to show worse 1-year survival after propensity matching, it is important to know in which cases surgery is beneficial.

We therefore conclude that the indication for surgery might be beneficial when CoNS are detected to avoid relapse and improve 1-year survival.

#### V 16

##### Changes in frailty among patients with spinal pathologies during the first 5 waves of the COVID-19 pandemic in a nationwide hospital network in Germany

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**Introduction:** In patients with degenerative spinal disease, higher degrees of frailty, as measured by the Hospital Frailty Risk Score (HFRS), are associated with poor treatment outcomes. The COVID-19 pandemic has led to significant increases in frailty among hospitalized patients. We present the first nationwide analysis of the impact the COVID-19 pandemic has been having on frailty among spine patients.

**Methods:** In this retrospective study we examined administrative data from a nationwide network of 76 hospitals in Germany with emphasis on HFRS, types of treatment and outcomes. We compared data from the last year prior to the pandemic (2019) to the first 5 waves of the pandemic (Jan 1, 2020 – May 17, 2022). All patients with a primary diagnosis of degenerative, traumatic or infectious spinal disease were included. The following HFRS groups were compared to each other: low (< 5 points), intermediate (5–15 points), and high (> 15 points).

**Results:** Of the 379,910 included cases with spine pathologies 168,481 were hospitalized during the pandemic, and 194,722 in 2019. Compared to pre-pandemic levels, hospital admissions for spinal pathologies decreased significantly during all 5 waves of the pandemic and the proportion of spine patients with high HFRS increased from a range of 5.8–6.1% to 6.5–8.8% ( $p<0.01$ ). Analogously, during all 5 waves, there was a significant increase in patient age (from 65.3–65.5 years to 65.8–66.5 years;  $p<0.01$ ). The rate of comorbidities increased significantly, as well, with a rise in the Elixhauser Comorbidity Index from a range of 4.2–4.3 to 4.7–5.9 ( $p<0.01$ ). Throughout the pandemic, there was a significant increase in the rate of spinal fusion procedures among patients with low HFRS (from a range of 6.4–6.8% to 8.4–10.3%;  $p<0.01$ ), as well as in the intermediate HFRS group (from 5.8–6.0% to 6.9–7.8%;  $p<0.01$ ). No changes in rates were observed for decompressive spine procedures, disc hernia resections, or kyphoplasty. Throughout all 5 pandemic waves, patients of the high HFRS group displayed significantly higher in-hospital mortality rates (8.6–13.6%) compared to patients in the low HFRS group (0.1–0.4%;  $p<0.01$ ).

**Discussion:** We present the largest study, to date, on frailty among patients with spinal pathologies in Germany. Our findings suggest that the COVID-19 pandemic has led to decreased numbers of hospital admissions for spinal pathologies but increased frailty among those hospitalized. This type of "negative selection" may be due to younger and healthier spine patients avoiding hospitalization out of fear of hospital-acquired COVID-19 infection. Among hospitalized spine patients with low or intermediate levels of frailty, the rate of spinal fusion procedures increased during the pandemic, while rates of non-fusion procedures were not impacted.

## V 17

**Glance into the black box – which patient-related factors influence the AI-based therapy prediction of lumbar disc herniations?**\*A. Wirries<sup>1</sup>, F. Geiger<sup>1</sup>, A. Hammad<sup>1</sup>, J. Eberl<sup>1</sup>, S. Jabari<sup>2</sup><sup>1</sup>Orthopädische Klinik, Hessing-Stiftung Augsburg, Wirbelsäulen- und Skoliosezentrum, Augsburg, Deutschland<sup>2</sup>FAU Erlangen-Nürnberg, Institut für Neuropathologie, Erlangen, Deutschland

**Introduction:** Decisions about conservative or surgical therapies for pain caused by lumbar disc herniation are often characterised by subjectivity. Therapy predictions by AI algorithms could serve as objective guidance. We present such an algorithm in the context of a prospective study as an application to predict ODI and VAS values. Thereby, we identify patient-related factors with the greatest influence on the predictions.

**Method/Materials:** All data were collected as part of a prospective observational study (DRKS00017595, ethics vote no. 16098). Since May 2020, 123 consecutive patients were included. To establish the machine learning, we defined VAS for leg pain and ODI score at 6 weeks, 6 months and 1 year after treatment, respectively, as target predictive values. The total data were read as a csv file via pandas python package (pandas v. 0.23.1; python 3.6.7), basic statistical analyses were performed (using matplotlib v. 2.1.2, seaborn v.0.8.1, feature selector v.1.0.0, scikit-learn v.0.21.2) and a training and a test dataset were defined by stratified data distribution. A reduction in complexity was achieved through recursive feature elimination, weighting and analysis of intercorrelating features, and a neural network was trained with the final features (Keras framework v. 2.2.4 with Tensorflow backend v.1.12.0). Different machine learning algorithms were tested for their performance, with a decision-tree regressor achieving the most stable prediction values. An analysis of the algorithm operations allowed the identification of the most important patient-related factors of the predictions.

**Results:** The evaluations were performed in a 10-fold cross-validation. The difference between predicted and real ODI value was between 8.6 and 10.0 points on the ODI scale ranging from 0 to 100 and between 1.79 and 1.97 points on the VAS scale ranging from 0 to 10. Thus, the absolute deviations for both values are within the described minimally clinically important differences (MCID) for these values and can be considered sufficient for routine application. The analysis of the most important influencing factors demonstrated a primary orientation of the algorithm towards the HADS score for anxiety disorder, followed by the patient's BMI and the SF-36 score for general health.

**Discussion:** With this study, we present an AI model for the course of therapy after lumbar disc herniation by predicting ODI and VAS values. We can show which factors influence the AI decision, making it possible to draw general conclusions about the clinical picture. To the best of our knowledge, this is the first representation of the "thinking process" of an AI in lumbar disc herniations. Interestingly, it shows that psychological factors and self-perception of health, along with BMI, are major factors in predicting the course of pain in this condition.

## V 18

**Is finger-to-floor distance a valid marker of lumbar mobility in patients with and without chronic low back pain? An analysis of 523 participants**\*L. Becker<sup>1,2</sup>, F. Schömig<sup>1,2</sup>, L. M. Cordes<sup>2</sup>, G. N. Duda<sup>2</sup>, M. Pumberger<sup>1</sup>, H. Schmid<sup>2</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Centrum für Muskuloskeletale Chirurgie (CMSC), Berlin, Deutschland<sup>2</sup>Charité – Universitätsmedizin Berlin, Berlin Institute of Health, Julius Wolff Institute for Biomechanics and Musculoskeletal Regeneration, Berlin, Deutschland

**Background:** Finger-to-floor distance (FFD) as a combined movement of hip flexion with pelvic tilting and trunk flexion is often used as a simplified measure for the assessment of spinal mobility during clinical examination of the spine. Especially for patients with low back pain (LBP), the detection of movement

deficits to restore function is a relevant diagnostic parameter. However, the extent to which the FFD represents lumbar mobility is unclear.

**Methods:** We prospectively included 523 participants, 167 subjects had chronic LBP >12 weeks. We assessed FFD in maximal trunk flexion with extended knees; we recorded the resulting lumbar flexion and hip flexion using the validated, non-ionizing Epionics SPINE measurement system (Epionics Medical GmbH, Potsdam, Germany). We matched participants with low back pain by age, sex, height, and body mass index (BMI) with an asymptomatic control group, resulting in a cohort of 120 individuals with LBP and an asymptomatic control group of 120 participants.

**Results:** In the entire cohort of 523 participants, FFD at maximum trunk flexion was 6.3 cm±18.3 cm (mean±standard deviation). Maximal trunk flexion resulted in a pelvic anteversion of 72.2°±21.2° and a reduction in lumbar lordosis of 46.9°±13.7°. Considering the whole collective, there was a negative correlation between FFD and pelvic anteversion (p<.001, r=-.548) and a weak negative correlation with lumbar flexion (p<.001, r=-.442). In the matched cohorts of 120 subjects, participants with LBP demonstrated significantly reduced FFD (LBP 22.5(±21.5) cm, Control -0.6(±11.6) cm, p<.001) and significantly reduced pelvic anteversion (LBP 59.4(±22.7)°, Control 73.5(±18.6)°, p<.001) and lumbar flexion (LBP 36.7(±12.8)°, Control 49.9(±11.4)°, p<.001) under maximal trunk flexion. For the asymptomatic control group, a weak correlation (p<.001, r=-.348) was found between FFD and pelvic anteversion and lumbar flexion (p<.001, r=-0.184). Subjects with LBP had a moderate negative correlation between FBA and pelvic anteversion (p<.001, r=-.663) and a weak correlation with lumbar flexion (p<.001, r=-.432).

**Conclusions:** While there is only a weak correlation of lumbar flexion and pelvic anteversion with FFD in participants without back pain, our study presented a moderate correlation to pelvic anteversion in participants with LBP. Therefore, FBA is not a valid marker of lumbar mobility for both participants with and without LBP.

## V 19

**Three-year durability of restorative neurostimulation effectiveness in patients with chronic low back pain and functional instability of the lumbar spine**\*C. Gilligan<sup>1</sup><sup>1</sup>Harvard Medical School – Brigham and Women's Hospital, Spine and Pain Management Center, Chestnut Hill, MA, USA

**Objective:** Patients with refractory chronic low back pain (CLBP) associated with multifidus muscle dysfunction, functional instability of the lumbar spine and no indications for spine surgery, have a poor prognosis and few treatment options with durable effectiveness. An implantable restorative neurostimulator (ReActiv8® by Mainstay Medical) stimulates the medial branches of the L2 dorsal rami to override underlying inhibition of the multifidus muscles and facilitate motor control restoration. An international, sham-controlled, pivotal trial provided evidence of safety and effectiveness (clinicaltrials.gov/show/NCT02577354).<sup>1</sup> Here we present the 3-year longitudinal analysis.

**Material/Methods:** Eligible patients had CLBP (VAS≥6 cm; Oswestry Disability Index ODI≥21 points) despite treatment including at least pain medications and physical therapy, evidence of multifidus dysfunction (positive prone instability test) and no surgical indication. Participants activated stimulation for up to 30 minutes twice daily and outcomes were assessed through 3-years after activation. To provide implicit imputations of randomly missing data, the mixed-effects model repeated measures (MMRM) approach was used for continuous outcomes and Multiple Imputation (MI) for proportions.

**Results:** At baseline (N=204), participants were 47±9 years of age, had history of 14±11 years of back pain, an average low back pain VAS of 7.3±0.7 cm, ODI of 39±10, EQ-5D of 0.585±0.174 points with pain on 97±8% of days in the year prior to enrollment. After 3 years (N=133), mean average VAS improved by 4.9±0.2 cm, ODI by 22.7± 1.3 points and EQ-5D by 0.220±0.017 (all P<0.0001) approaching the age-matched population norm; 77% of participants

had  $\geq 50\%$  VAS improvement; 67% reported LBP-Resolution (VAS $\leq 2.5$  cm); 63% had  $\geq 20$ -point ODI improvement and 83% reported improvement of  $\geq 50\%$  in VAS and/or  $\geq 20$  points in ODI. Of participants using opioids at baseline, 71% had voluntarily discontinued or decreased consumption. Attenuation of effectiveness in the imputed (N=204) analyses was relatively small and did not affect statistical significance and clinical relevance of these results. Overall safety compares favorably to available neurostimulation systems, and no lead migrations were observed.

**Conclusions:** Three-year follow-up data of this pivotal trial demonstrates that restorative neurostimulation is effective, durable, and safe. It provides surgeons with a reversible and targeted treatment option for patients with refractory CLBP associated with functional instability of the lumbar spine and no indications for surgery. Robust study design, extended follow-up duration and conservative statistical analysis instill confidence in the presented results and conclusions.

<sup>1</sup>Gilligan C, Volschenk W, Russo M, et al. An implantable restorative-neurostimulator for refractory mechanical chronic low back pain: a randomized sham-controlled clinical trial. *Pain*. 2021;162(00):2486-2498.

## V 20

### Secondary dislocations after stabilization surgery of the subaxial cervical spine in type B injuries with concomitant facet joint injury

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**Background:** AO Spine type B injuries of the subaxial cervical spine (sCS) can be associated with different facet joint injuries (FI), which are classified from F1 to F4 according to increasing instability. Type F1 FI are considered stable, type F2 are considered potentially unstable, and type F3 and type F4 FI are considered unstable. This study aimed to determine whether in type B injuries of the sCV (i) the presence and instability of a concomitant FI influences the rate of secondary dislocations after surgical stabilization and, (ii) whether the dislocation rate in unstable FI is dependent on the stabilization surgery (anterior, posterior, combined).

**Methods:** A retrospective analysis of clinical data of patients with surgery for type B injuries of the sCS in a national trauma center from 2010 to 2020 was performed. Concomitant FI were classified according to AO Spine. Patients were divided into a group without unstable FI (no FI or F1, group "Stab") and a group with unstable or potentially unstable FI (F2 – F4, group "Unstab") and the frequency of secondary dislocations within 60 days after surgery was compared between the groups.

To compare stabilization surgery for unstable FI, the "Unstab" group was divided into a subgroup with anterior stabilization alone and a subgroup with posterior or combined stabilization surgery, and the rates of secondary dislocations between the groups were compared.

The statistical analysis was performed using 2x2 contingency tables and Boschloo's test (R/JASP). The level of significance was set to  $p < 0.05$ .

**Results:** 135 patients were included. The frequencies of the different FI were as follows: No FI: 71 (52.6%); F1: 20 (14.8%); F2: 28 (20.7%); F3: 5 (3.7%); F4: 11 (8.1%). Thus, 91 patients (67.4%) fell into the "Stab" group and 44 patients (32.6%) into the "Unstab" group. The two groups were comparable concerning age, gender, and Injury Severity Score.

No secondary dislocations occurred in the "Stab" group (0.0%); 5 secondary dislocations occurred in the "Unstab" group (11.4%). This difference was statistically significant ( $p = 0.0024$ ).

In the "Unstab" group, 21 patients received anterior stabilization alone, here 4 secondary dislocations occurred (19.0%). Only 1 secondary dislocation occurred in the 23 patients with posterior or combined stabilization (4.3%). This difference was not statistically significant ( $p = 0.0925$ ).

**Conclusions:** The rate of secondary dislocations is significantly increased in type B injuries of the sCS according to AO Spine if there is an accompanying unstable or potentially unstable FI. The dislocation rates in this subgroup of patients are higher with anterior stabilization alone than with posterior or combined stabilization, yet without statistical significance. This study is limited by its endpoints low frequency of observation.

## V 21

### Pull-out resistance of Facet versus Laminar C2 screws – an experimental comparative biomechanical investigation

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**Background:** Trans-pedicular or trans-isthmic screws for C2 instrumentation represent the gold standard; however, the anatomy is not always compatible (hypoplastic pedicles, procidentia of the vertebral artery). Alternatives have been proposed, using laminar screws or, recently, bicortical facet screws.

**Research question:** To date, no biomechanical studies have compared facet versus laminar screws of C2. We propose a morphometric analysis and a pull-out strengths comparison of both techniques.

**Study design:** *In vitro* randomized comparative biomechanical study.

**Methods:** Thirty-two human cadaveric C2 vertebrae benefited from a CT-scan imaging and a Dual X-Ray Absorptiometry before receiving both techniques, randomized according to side and sequence. Screws positioning was verified using 2D X-rays. Sixty-four mechanical tests were performed using pure tensile loading along the axis of the screws until pull-out. The mean pull-out strengths were compared using paired tests, multivariate and survival analysis (Kaplan-Meier curves).

**Results:** The morphometric data were consistent with previous studies. Regarding the 64 tests, the mean pull-out strength of laminar screws ( $707 \pm 467$  N) was significantly higher than that of facet screws ( $390 \pm 230$  N) ( $p = 0.0004$ ). Bone mineral density was moderately positively correlated with pull-out strength ( $r = 0.42$  for facet screws and  $r = 0.3$  for laminar screws). Both techniques were mechanically equivalent when an intra-laminar cortical grip was not achievable for laminar screws. The mean pull-out strength for LS with laminar cortical grip ( $1071 \pm 395$  N) was significantly higher than that of LS without ( $423 \pm 291$  N) ( $p < 0.0001$ ).

**Discussion:** Our results strongly suggest that bicortical facet screws of C2 offer less mechanical resistance (almost half lower) than laminar screws, except if the intra-laminar grip is not achievable. Alternative loading biomechanical scenarios may be investigated to further confirm these results.

Fig. 1

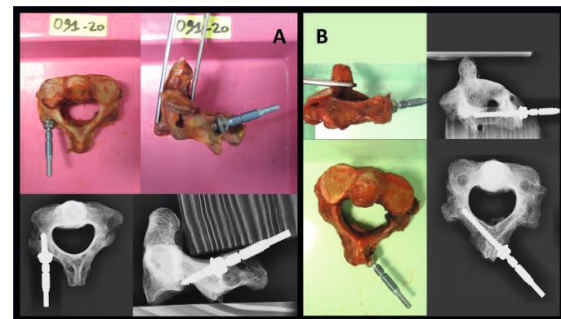
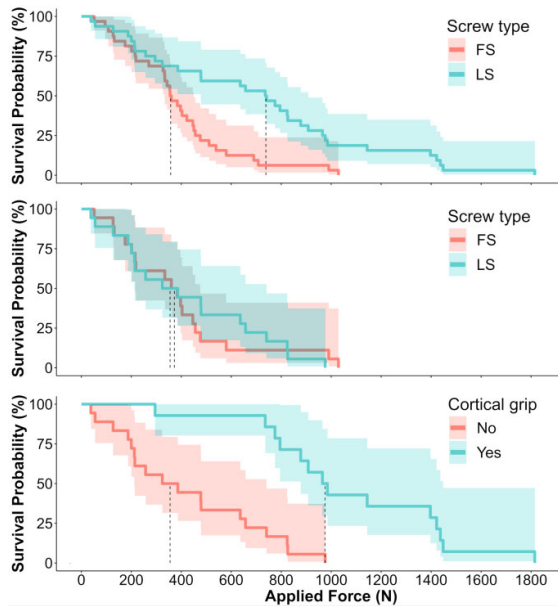


Fig. 2



## V 22

### Posttraumatic disruption of the Blood-Spinal-Cord-Barrier in the acute and subacute phase is aggravated by the endothelial cell-specific knock-out of Ephrin-B2 after experimental Spinal Cord Injury

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**Background:** The disruption of the Blood-Spinal-Cord-Barrier (BSCB) is a leading pathophysiology in traumatic Spinal Cord Injury (SCI), and its restitution plays a crucial role in spinal cord regeneration. The guidance molecule Ephrin-B2 promotes cell-cell-contacts in the neurovascular unit. However, its specific role in endothelial cells following SCI is unknown. With this study, we characterize the posttraumatic BSCB disruption and restitution dependent on the endothelial cell-specific knock-out (KO) of Ephrin-B2 in a mouse model up to 7d post SCI.

**Methods:** Adult CDH5-CreERT2-Efmb2lox/lox (KO) and littermate wildtype (WT) mice (m/f, n=66) underwent mid-thoracic (Th6/7) clip-compression SCI via modified aneurysm clip (5g, 60s) or sham-injury (two-level laminectomy). Endothelial cell-specific Ephrin-B2 KO was induced via the promotor CDH5 in a cre-lox-system with consecutive injections of tamoxifen (5d period). Neurobehavioral analysis was performed (n=16) using Catwalk® gait analysis and Basso Mouse Scale at 1, 3, and 7d post SCI. Additionally, *in vivo* 7Tesla-MRI was performed, and individual specimens were sacrificed for qualitative histological analysis at each time point (LFB+H&E; CD31+Evans-Blue, n=31). BSCB disruption was quantified using Evans-Blue fluorescence assay (Tecan, n=35). Animal experimental permission was granted (G031417).

**Results:** Quantitative assessment of EVB-extravasation displayed a significant BSCB disruption in KO SCI animals compared to WT SCI animals at 1d and 3d but not at 7d post SCI (1d:p=0,0107, 3d:p=0,0002, 7d:p=0,1785). Neurobehavioral analyses showed no

differences between KO SCI and WT SCI animals, with no significant regaining of hindlimb function in the course up to 7d post SCI in both groups (1-7d:p>0.05).

**Conclusion:** Ephrin-B2 signaling plays a significant role in BSCB maintenance and repair, as the posttraumatic BSCB disruption is aggravated by the endothelial cell-specific KO of Ephrin-B2, leading to aggravated secondary injury. Whilst no significant recovery of hindlimb function is achieved post SCI up to 7d, analyses of longer recovery periods are necessary to evaluate the impact on functional recovery.

## V 23

### Serum neurofilament light (NF-L) and glial fibrillary acidic protein (GFAP) biomarkers and their association with MRI findings in acute human traumatic spinal cord injury

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**Introduction:** Injury severity after traumatic spinal cord injury (SCI) in the acute setting is assessed by a standardized neurological examination that is subjective, poorly predictive of outcome and often impossible or severely confounded by pharmacological sedation, or concomitant injuries. Therefore, biomarkers that objectively characterize severity and are able to predict outcome are urgently needed for clinical decision-making, communication with patients and their families as well as study design. Preliminary data shows that serological values of NF-L and GFAP are interesting candidates for objective diagnostic and prognostic biomarkers. Previous studies also tried to assess magnetic resonance imaging (MRI) findings as potential surrogate markers for SCI. The following study aims to combine certain MRI findings with serum values of NF-L and GFAP as potential markers to characterize injury severity, predict outcome and eventually monitor treatment response.

**Material and Methods:** This is a retrospective analysis of prospective collected data. Patients with acute traumatic SCI were included in an observational trial in which serial serum samples were collected in the first 5 days after injury. The concentrations of NF-L as well as GFAP were analyzed using SimoaTM technology. ASIA impairment Scale (AIS) grade and motor scores were obtained according to the International Standards for Neurological Classification of Spinal Cord Injury at presentation and at 6-months post-injury. As MRI parameters we assessed the Maximal Canal Compromise (MCC), Maximal Spinal Cord Compromise (MSCC), intramedullary lesion length, intramedullary hemorrhage, AO Spine fracture classification, BASIC score and sagittal grade. We included all patients from our institution that were enrolled in the prospective trial and had preoperative MRI available.

**Results:** We included 74 patients. GFAP is rapidly released into the blood stream in a severity dependent manner, whereas NF-L increases within the first 5 days after injury. Both, GFAP and NF-L, are associated with motor scores. Further, they are associated with multiple MRI findings. Unbiased recursive partitioning revealed the BASIC Score, intramedullary lesion length as well as GFAP levels after 24 hours as the most important predictors for injury severity. Intramedullary lesion length in the preoperative MRI as well as GFAP levels after 72 hours were able to predict the neurological outcome after 6 months of follow-up.

**Discussion:** Initial data indicates that certain MRI parameters as well as serological GFAP levels qualify as potential biomarkers after acute human SCI to stratify patients according to the severity and may be able to predict outcome.

**V 24**

**Calcium sulfate/hydroxyapatite mediated controlled co-delivery of BMP-2 and zoledronic acid enhances spinal fusion in a rat model**

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**Introduction:** Spinal surgery aiming to fuse segments can be used to treat various pathologies, but fusion failure occurs in 25-35%. Bone morphogenetic protein-2 (BMP-2) is approved by FDA for spinal fusion, but it is also a strong inducer of osteoclast-based bone resorption, leading to a reduced net bone formation and limiting its clinical application in spinal fusion. In addition, the FDA-approved carrier (absorbable collagen sponge) used to deliver rhBMP-2 is sub-optimal and causes pre-mature release of the protein. Our recent study showed an excellent and cumulative effect on bone regeneration when both BMP-2 and zoledronic acid (ZA) were co-delivered from an optimized CaS/HA scaffold in a rat critical-size femoral defect model. Therefore, the aim of this study is to show whether local application of BMP-2 and ZA released from a resorbable CaS/HA scaffold is favorable for spinal fusion.

**Methods:** Based on the treatment i.e., implant type, 7 groups were set up in this study (I. CaS/HA, II. CaS/HA + BMP-2, III. CaS/HA + systemic ZA, IV. CaS/HA + local ZA, V. CaS/HA + BMP-2 + systemic ZA, VI. CaS/HA + BMP-2 + local ZA, VII. Blank (previous study of our group)). This in vivo study was performed on 132, 8-week-old male Wistar rats (n = 12 at 3 weeks and n = 10 at 6 weeks per group, animal protocol no. 25-5131/474/38). A posterolateral intertransverse process spinal fusion at L4 to L5 was performed bilaterally by implanting group dependent scaffolds (see above). At 3 weeks, 12 animals per group, and at 6 weeks 10 animals per group were euthanized for  $\mu$ CT and histological analyses. One-way ANOVA and Tukey's post-hoc test were used for statistical analysis between the groups.

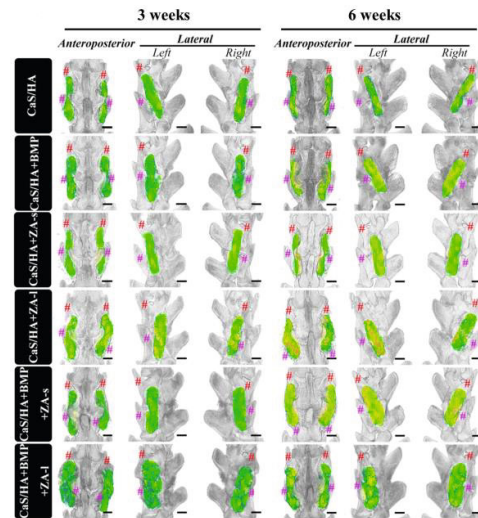
**Results:**  $\mu$ CT evaluation showed better spinal fusion results when the CaS/HA scaffolds were functionalized with BMP-2 and local ZA compared to other groups. The CaS/HA + BMP-2 + local ZA group had higher bone volume at 3 weeks, and higher bone volume and bone mineral density at 6 weeks. (Figure 1). In line with this, histological images revealed more new bone formation in CaS/HA + BMP-2 + local ZA than other groups (Figure 2).

**Discussion:** The CaS/HA-based biomaterial functionalized with bioactive molecules rhBMP-2 and ZA enhanced bone formation and concomitant fusion outcome. The CaS/HA biomaterial can be used as an ideal carrier of BMP-2 or ZA and the CaS/HA biomaterial with rhBMP-2 and ZA can potentially be used as an off-the-shelf alternative to autograft bone for spinal fusion.

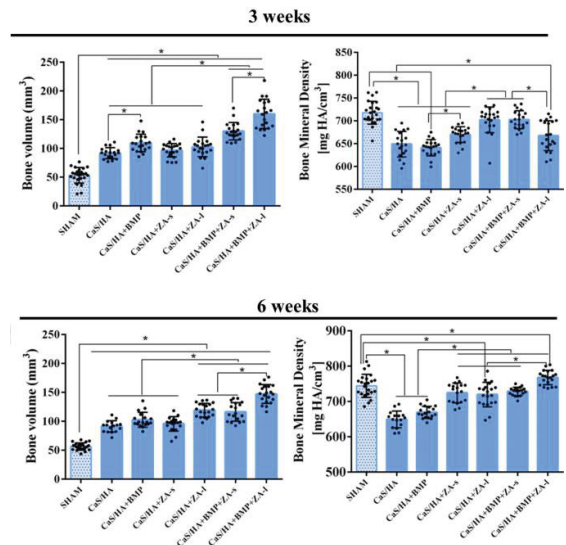
**Figure 1:** Micro-CT evaluation of spinal fusion. Representative 3D reconstructions at 3 and 6 weeks. The red # and pink # indicated the L4 and L5 transverse process, respectively. The red \* and pink \* indicated the L4 and L5 lamina, respectively. Scale bars = 2 mm.

**Figure 2:** Bone volume and bone mineral density at 3 and 6 weeks, quantified in all treatment groups using micro-CT. Data are presented as means  $\pm$  SD. \*P < 0.05.

**Fig. 1**



**Fig. 2**



**V 25**

**The Substance P pathway in the context of traumatic spinal cord injury – friend or foe?**

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**Introduction:** Traumatic spinal cord injury (tSCI) is a devastating event, often associated with lifelong disability. With the primary injury, a cascade of secondary injury processes including blood-spinal cord barrier (BSCB) disintegration and neuroinflammation is initiated, typically leading to aggravation of symptoms, impaired regeneration, and worsened outcome. The Substance P (SP) mediated pathway has been associated with mediating secondary injury cascades. Therefore, our current experiment aimed to assess the effects of an activation of the SP pathway on secondary injury processes in an animal model of tSCI.

**Material and Methods:** 78 Wistar rats were randomized to receive either a T10-compression/contusion SCI with additional implantation of a micropump for i.t.-delivery of SP or Placebo for up to 7 days, or a laminectomy only (Sham) Neurological function

was assessed 1, 3 and 7 days after SCI as well as weekly thereafter (CatWalk gait analysis, BBB openfield score and Gridwalk test). Animals were perfused at different timepoints (3, 7 and 28 days after SCI). After tissue preparation, immunofluorescence analysis was performed to assess the influence of SP on neuroinflammation, and BSCB integrity in the acute phase after tSCI. Furthermore, the wet/dry weight method was used to assess spinal cord edema. Results between groups were statistically compared ( $p < 0,05$  was considered significant).

**Results:** Recovery of neurological function showed an association with the i.t. SP-treatment: BBB scores were clearly higher in SP animals compared to Placebo animals and stepping errors in the Gridwalk test as well as gait parameters in the CatWalk gait analysis trended towards better outcomes with the administration of SP. Nevertheless, the i.t. administration of SP directly after tSCI did not strongly reduce neuroinflammation or increase BSCB-integrity compared to Placebo animals on a histological level. Accordingly, spinal cord edema, measured with the wet/dry weight method was only slightly reduced in the SP group compared to the Placebo group.

**Conclusion:** We present findings on the association of the SP pathway with neuroinflammation, BSCB integrity, spinal cord edema as well as functional recovery after tSCI in rats. Whether activation or rather blockage of this pathway might exert neuroprotective effects and might thus be useful for further preclinical studies will be discussed.

#### V 26

##### Analysis of factors influencing surgery-related complications after stabilization of the injured subaxial cervical spine

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**Background:** Complications of stabilization surgery of the injured subaxial cervical spine (sCS) can have severe consequences: Secondary dislocations can lead to spinal cord injury, soft tissue injuries or infections can lead to functional impairment of vital structures such as the trachea and larynx. This study aimed to determine the frequency and type of severe surgery-related complications and to analyze the factors that favor the occurrence of complications.

**Methods:** We performed a retrospective analysis of clinical data of patients with surgery for sCS injuries in a national trauma center from 2010 to 2020. Surgical complications within the first 60 days after surgery were recorded and classified based on their severity according to Clavien-Dindo. The patient group with severe surgical complications (Clavien-Dindo III and IV) was compared to the group without severe surgical complications regarding different potential influencing factors. The statistical evaluation was performed with IBM SPSS Statistics 27. The level of significance was set to  $p < 0.05$ .

**Results:** A total of 292 patients were included. Severe surgical complications (Clavien-Dindo III and IV) occurred in 49 patients (16.8%). Severe complications related to the surgical approach (wound healing disorders requiring revision, hematoma, etc.) occurred in 34 patients (11.6%). Complications related to reduction and fixation (secondary dislocation, implant loosening and malposition) in 16 patients (5.5%). Severe recurrent nerve palsy, nerve root lesion and postoperative paraplegia occurred in one patient (0.3%) each. No death was directly attributable to a surgical complication. Patients with severe surgical complications were on average 8.9 years older (95% CI [3.6; 16.1],  $p = 0.002$ ). They more frequently had pre-existing conditions of the spine ( $p = 0.047$ ) as well as complexity factors (e.g. critical disc herniation, stiffening bone disease) according to AO Spine classification ( $p = 0.016$ ) than patients without severe surgical complications. Posterior and combined stabilization led to a significantly higher surgical complication rate than anterior stabilization alone ( $p = 0.025$ ). Other preexisting conditions ( $p = 0.560$ ), the use of anticoagulants or antiplatelet medication ( $p = 0.058$ ), the presence of spinal cord injury ( $p = 0.487$ ) and the total duration of surgery ( $p = 0.946$ ) had no statistically significant influence.

**Conclusions:** Despite advances in surgical technique and perioperative management, complications of stabilization surgery of the injured sCS remain frequent. Patient age as a relevant predictor for complications illustrates the particular vulnerability of the steadily growing group of older people with sCS injuries. Posterior stabilization is associated with more complications than anterior stabilizations.

#### V 27

##### Treatment and outcome of osteoporotic thoracolumbar vertebral body fractures with deformation of both endplates with or without posterior wall involvement (OF 4) – short-term results from the prospective EOFTT multicenter study

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**Objective:** To analyse therapeutical strategies applied to osteoporotic thoracolumbar OF 4 injuries with deformation of both endplates with or without posterior wall involvement and to assess related complications and clinical outcome.

**Methods:** Subgroup analysis of a multicenter prospective cohort s(OEFTT). The study was conducted at 17 spine centers including 518 consecutive patients who were treated for an OVCF. For the present study, only patients with OF 4 fractures were analysed. Outcome parameters were complications, Visual Analogue Scale, Oswestry Disability Questionnaire, Timed Up & Go test, EQ-5D 5L, and Barthel Index after a minimum follow-up of 6 weeks.

**Results:** A total of 152 (29%) patients presented with OF 4 fractures. 76% were female and the mean age was 76 (range 41–97). The majority of fractures were located at the thoracolumbar junction (68%). The most common treatment was short segmental posterior stabilization (51%) including augmentation of the fractured vertebral body (hybrid stabilization) in 36%. Conservative treatment, stand-alone cement augmentation, long segmental stabilization, and dorsoventral stabilization was performed in 24%, 17%, 15%, and 7%, respectively. Complete data set of clinical outcome parameter at follow up (208±131 days) was available in 101 patients. The mean ODI was 33, without significant between the therapy strategies. The inpatient complication rate was 8% in the conservatively group and 25% in surgically treated group. During follow-up period 14% of the conservatively patients and 4% of the surgical treated patients experienced neurological deficits.

**Conclusions:** Conservative therapy seems to be viable in those cases with only mild to moderate symptoms. Posterior percutaneous short-segmental stabilization with augmentation of the fractured vertebral body was the dominant treatment strategy leading to promising clinical short-term results. Stand-alone cement augmentation seems to be a valid alternative in selected cases.

#### V 28

##### Long-term follow-up after vertebroplasty – a 10-years control study

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**Introduction:** Osteoporotic compression fractures affect million of people every year with increasing numbers due to demographic changes. Although vertebroplasty is an established method and has been around since 1987, there are to our knowledge surprisingly no published long-term results. Randomized controlled trials published since 2009 have demonstrated conflicting results regarding benefit in pain reduction and functional improvement.

**Methods:** All patients who underwent vertebroplasty in our initial prospective monocenter case series from May 2007 until July 2008 were contacted for a minimum-10 years follow-up in July 2018. Patients were evaluated regarding radiologic outcome and self-reported outcome parameters (PROs). Gathered parameters remained unmodified to the initial ones analyzing QoL improvement (EQ5D 3L and NASS score) and pain alleviation (VAS, NRS). Taking into account the high patient age, mortality was defined as an additional endpoint. Exclusion criteria was additional instrumentation, use of additional devices such as kyphoplasty balloons/ stentoplasty, cognitive impairment, insufficient radiology or absent re-consent.

**Results:** Out of 241 patients eligible from the initial study (all patients) 186 (77.2%) deceased in the meantime. 49 (20%) were available for re-assessment with a mean follow-up of 10.5 years (9.9–11.1). Of those 30 (12.4%) were assessed clinically and radiologically, 16 (6.6%) in written form and three (1.2%) by phone only. 6 patients were LTFU. At 10 years patients reported a consistently improved quality of life (EQ-5D;  $p < 0.01$ ) and global satisfaction (NRS). Vertebroplasty had a significant impact on back pain over 10 years ( $p < 0.001$ ). 50% experienced a fracture free period since the index procedure.

**Conclusion:** Vertebroplasty has an early impact on quality of life and back pain, which is still significant at 10 years follow-up. Patients over 80 years of age undergoing such an intervention have a 10-year mortality rate of 77%.

#### V 29

##### Influence of psychological stress on outpatient treatment of patients with spinal disorders

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**Introduction:** The diagnosis and treatment of spinal disorders in the outpatient setting in Germany is characterized by a highly interdisciplinary approach. In many cases, this treatment takes place over months to years. In this context, psychological stress as a comorbidity is often underestimated. The aim of our study was to assess the extent of psychological distress in spine patients in the outpatient setting and to analyze the impact on the course of treatment.

**Material and Methods:** We conducted a prospective, questionnaire-based, single-center study of all patients who presented for the first time to our university-based Spine Center (Neurosurgery, Orthopedic and Trauma Surgery) in 2019 – 2022. Patients completed the PHQ-9 mental health questionnaire. Additional parameters ( $n=60$ ) were queried using multiple-choice format. All patients provided written informed consent (Ethics Vote PV5904).

**Results:** In total, we analyzed questionnaires from 875 patients. Patients reported frequent or daily exposure to psychological distress in 40.3% of cases. High psychological distress correlated significantly with the number of physician contacts ( $p=0.001$ ), with incapacity to work (low psychological distress: 49.6% vs. high distress 68.4%,  $p < 0.001$ ) and with the number of radiological examinations ( $p < 0.05$ ). High psychological distress correlated with the use of osteopathy ( $p=0.06$ ) and homeopathy ( $p=0.017$ ), but not with the use of acupuncture ( $p=0.8$ ). In this regard, severely psychologically distressed patients reported frequent to daily suicide-like thoughts in  $>10\%$  of cases. In addition, significant

correlations were found with the use of pain medication, as well as the presence of comorbidities.

**Discussion:** Our study showed that psychological distress in patients with spinal disorders plays a central role in outpatient care and correlates with both the use of alternative cures and the medical care structure (physician contacts/imaging). Our results indicate that early psychological diagnosis and consequently co-treatment is indicated in patients with back disorders. Furthermore, a presentation to an experienced spinal therapist/surgeon should be made early in the course so that targeted diagnostics and therapy can be started quickly.

#### V 30

##### Intravenous antibiotic treatment in patients with spinal infections in the outpatient setting – a feasibility study

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**Introduction:** Spondylodiscitis, spinal empyema and postoperative wound infections often require a long-term intravenous antibiotic treatment. To prevent an extensive hospital stay, intravenous antibiotic treatment can be performed in independent patients in an outpatient setting. Current literature supports its advantages, but there is a lack of data regarding neurosurgical spine patients. We hereby provide evidence of the feasibility and potential benefits of the outpatient antibiotic treatment of spinal infections.

**Material/Methods:** We prospectively enrolled all patients eligible for outpatient antibiotic treatment in our neurosurgical department from 2019–2022. We assessed inflammation markers, the clinical status and the length of hospital stay and readmittance.

**Results:** In total, we enrolled 27 patients. We included patients suffering from a postoperative deep wound infection (40%), spondylodiscitis patients (18%) and patients suffering from a low grade implant infection (29%). In 22 patients we identified specific bacteria causing the infection (mostly *Staphylococcus aureus*). Median length of hospital stay was 9 days, length of the antibiotic intravenous treatment was 4 weeks (range 2–16 weeks). In total, we were able to provide 649 days of intravenous antibiotic treatment in the outpatient setting. The readmittance rate was 7%.

**Discussion:** Outpatient antibiotic treatment provides a valid alternative for independent patients requiring long-term intravenous antibiotics for spinal infections. All but two patients were successfully treated and described a high contentedness with the outpatient treatment.

#### V 31

##### Imaging quality and radiation dose of spinal Photon-Counting Computed Tomography

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**Introduction:** Planning and follow-up of spines surgeries frequently require repeated computed tomography (CT) imaging, representing a considerable radiation exposure. Further CT imaging is susceptible to artifacts caused by metallic implants, which represent a challenge for the radiologic interpretation of

surrounding tissue. Novel CT technology based on spectral photon-counting detectors (PC-CT) may potentially improve diagnostic confidence, decrease imaging artifacts and reduce radiation dose in comparison to conventional energy-integrating CT (EID-CT).

**Methods:** In a prospective trial 32 patients underwent clinically indicated PC-CT of the spine (17 cervical, 3 thoracic, 12 lumbar). Axial reconstructions were performed using standard bone kernel (PC-CTstd) and monoenergetic (130kV) images (PC-CT130kV) exploiting the spectral PC-CT data (Fig. 1). For 17 of 32 patients prior EID-CT of the spine was available and was used as an intrinsic reference. For the remaining 15 patients, a matched (age, sex, BMI) EID-CT cohort was used. Image quality of PC-CTstd and EID-CT was randomly assessed in a triplanar view according to 5 parameters (overall quality, sharpness, artifacts, noise, and diagnostic confidence) by four radiologists blinded to the scanner type, on a 5-point Likert scale (1: non-diagnostic, to 5: excellent). For 10 patients where metallic implants were present, the image quality of PC-CTstd vs. PC-CT130kV was similarly evaluated. Finally, the radiation exposure of PC-CT and EID-CT was compared using the Computed Tomography Dose Index (CTDIvol).

**Results:** Comparing PC-CTstd to EID-CT, edge sharpness was rated significantly higher ( $p=0.003$ ) and noise significantly lower ( $p<0.001$ ) while the overall image quality, artifacts and diagnostic confidence revealed no difference ( $p\geq 0.05$ ). The radiation dose was significantly lower for PC-CTstd vs. EID-CT (mean CTDIvol: 8.83 vs. 15.71 mGy;  $p<0.001$ ). For metallic implants, the ratings for 130kV monoenergetic PC-CT130kV images vs. PC-CTstd were significantly superior for overall image quality, artifacts, noise and diagnostic confidence ( $p<0.001$ ).

**Discussion:** Spinal imaging using innovative PC-CT provides significantly higher imaging quality compared to conventional energy-integrating CT, especially in the presence of metallic implants, while simultaneously reducing radiation dose by 44%. This is of special clinical relevance as planning and postoperative follow-ups in case of complications (e.g. loosening of screws) may require repeated CT imaging.

**Fig. 1**

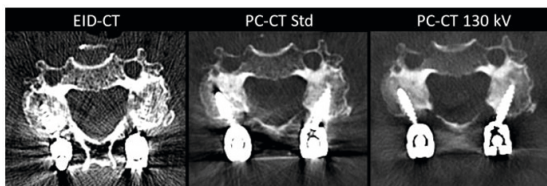


Abb. 1: Beispiel einer zervikaler Spondylodese. Die Artefakte sind am stärksten in der EID-CT ausgeprägt (links). Die Massa-lateralis-Schrauben in HWK 3 sind am besten in der PC-CT<sub>130kV</sub> abgrenzbar (rechts).

### V 32

#### Screening for Degenerative Cervical Myelopathy (SCREEN-DCM) in patients based on signs, symptoms and known risk factors – preliminary Results

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**Objective:** Degenerative Cervical Myelopathy (DCM) is the most common cause of spinal cord impairment. Unfortunately, DCM remains poorly recognized and underdiagnosed. To better identify these patients, a screening test for individuals at high risk of DCM, focusing on lumbar degenerative disease (LDD), was developed

and undertaken at multiple centers in an effort to uncover a diagnosis of DCM.

**Materials/Methods:** A screening test based on signs/symptoms and risk factors of DCM was designed and performed in neurosurgical consultations. A survey of 13 neurosurgeons was used to develop screening criteria for undertaking a cervical MRI. Points are attributed based upon signs/symptoms and comorbidities that predispose or are associated with DCM (e.g. carpal tunnel). Patients with <sup>3</sup> points undergo a cervical MRI. Patients with positive MRIs are consulted, and management is based on practice guidelines. An exploratory multivariate analysis of the effectiveness and efficiency will be evaluated after positively screening 50 patients.

**Results:** Out of 130 patients, 41 screened positive and 30 had a subsequent MRI. Of the 30, 11 (36.7%) were diagnosed with DCM (9/11 presented with T2 hyperintensity), and 3 (10%) were operated. The average number of points for patients screening positive with a diagnosis of myelopathy was 4.71 vs 3.75. All patients with myelopathy were considered as mildly myelopathic. Additionally, 7 of the 30 patients presented with mild stenosis without clear radiological evidence.

**Conclusion:** Screening for DCM in patients with lumbar pathology is effective for uncovering cervical myelopathy. These are preliminary results and a complete and more extensive analysis from this multicenter study are expected later this year.

### V 33

#### Detection of T2 hyperintensities through an automated spinal cord signal intensity analysis in patients with degenerative cervical myelopathy

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**Objectives:** The detection of T2 hyperintensities in patients with degenerative cervical myelopathy (DCM) is done subjectively in clinical practice. To gain an objective quantification for dedicated treatment, a signal intensity analysis of the spinal cord seems to be purposeful. Thus, we investigated a fully automated quantification of the T2 signal intensity (T2-SI) of the entire cervical spinal cord based on a high-resolution T2 MRI segmentation.

**Methods:** We prospectively analyzed 3D T2 SPACE sequences of the cervical spine of 114 symptomatic patients and 88 healthy volunteers. The spinal cord was segmented through an automated trained deep convolutional neuronal network with subsequent T2-SI registration for the whole spinal cord slice by slice (Fig. 1). The received T2-SI curves were subdivided for each cervical level from C2 to C7 (Fig. 1 exemplary for level C5/6). Three independent experts additionally evaluated all cervical levels concerning a subjective present T2 hyperintensity sign. For levels with a T2 hyperintensity, the corresponding T2-SI curve was compared to the curve of an age-matched healthy volunteer at the identical cervical level.

**Results:** 49 of 114 patients showed a subjective present T2 hyperintensity, predominantly at level C4/5 (n=15) and C5/6 (n=22, Fig. 2). The T2-SI curves of all subjectively T2-positive rated levels showed a higher variability reflected by standard deviation and range of the T2-SI within the spinal cord (Fig. 1+2). The proportion of the range from the mean T2-SI at the particular level, termed as "T2 myelopathy index" (T2-MI), was correspondingly significantly different for the levels C4/5, C5/6 and C6/7 ( $p<0.001-0.002$ ), with a trend for C6/7 ( $p=0.093$ , Fig. 2).

**Discussion:** This fully automated quantification of the T2-SI of the spinal cord was able to reveal a significantly different variability of the T2-SI in patients with DCM and subjectively present T2 hyperintensity compared to healthy volunteers. Whilst the absolute T2-SI values are not applicable due to known individual imaging

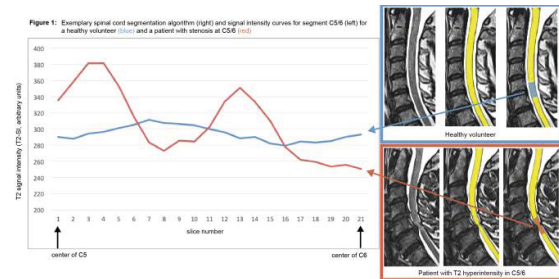


conditions, we introduced the inter-individually comparable T2 myelopathy index at every cervical level, showing corresponding significances. This automated, innovative procedure has the potential for diagnosing radiological DCM more objective and standardized, thus optimizing the recommendation for treatment. The determination of cut-off values and diagnostic accuracy are under further investigation.

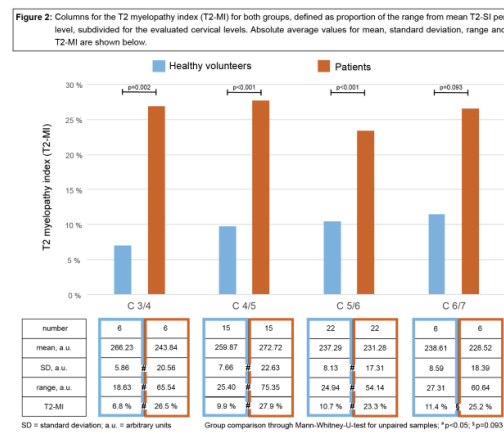
**Fig. 1:** Evaluation procedure of two subjects: The signal intensity curve at the level C5/6 of a T2-positive patient (red) shows a higher range of T2-SI through the affected segment compared to the matched healthy volunteer (blue).

**Fig. 2:** Results for T2-SI comparison between both groups (mean, standard deviation, range, T2-MI) showing significant different signal variability for the levels C3/4, C4/5 and C5/6.

**Fig. 1**



**Fig. 2**



**V 34**

**Influence of cervical total disc replacement on motion in the target segments and adjacent segments**

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**Introduction:** In contrast to cervical discectomy and fusion, total disc replacement (TDR) aims at preserving the motion at the treated vertebral level, thereby sparing the adjacent segments. Two-level TDR in particular is not sufficiently investigated yet. Therefore, the aim of this in-vitro study was to investigate the range of motion (ROM) of the cervical spine after one-level and two-level TDR in the target segments as well as the adjacent segments.

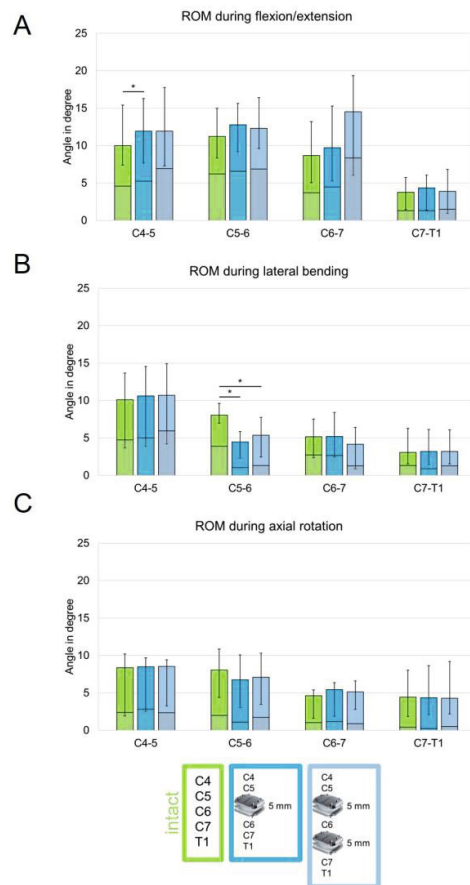
**Methods:** TDR was performed on six fresh frozen human cervical spine specimens (C4-T1, mean age 40 ± 17 years) first one-level at C5-6 and then extended one level further caudal (C5-7). In the intact state and after each implantation the ROM of the specimens was evaluated. Each specimen was quasistatically loaded with pure moments up to 1.5 Nm in flexion/extension (FE), lateral bending (LB) and axial rotation (AR) in a universal spine tester for 3.5

cycles at 1 °/s. Motion tracking was performed for each vertebral body individually to determine the ROM of each spinal level. Statistical analysis was performed using a Friedman-test and post-hoc correction with Dunn-Bonferroni-tests (p < 0.05).

**Results:** In FE, one-level TDR (C5-6) moderately increased the ROM in all four segments, but only significantly at the cranially adjacent segment C4-5 (Fig. 1 A). Additional TDR at C6-7 further increased the ROM at the target segment (p = 0.054) but did not influence the other segments. In LB, one-level TDR decreased the ROM at the target segment C5-6 significantly, without influencing the other segments (Fig. 1 B). Extending TDR to C6-7 decreased ROM in the target segment again but did not affect the adjacent segments. In AR, one-level TDR at C5-6 decreased the ROM at the target segment (p > 0.05) while ROM at the caudally adjacent segment C6-7 was increased (Fig. 1 C). Additional TDR at C6-7 did not further affect the ROM. At both segments C4-5 and C7-T1, the ROM was not affected by TDR at all.

**Discussion:** The motion preservation capabilities in FE as well as the reduction of motion in LB and AR are in line with previous studies of cervical TDR, however the influence on the motion of the adjacent segments is not regularly reported. In FE even one-level TDR results in increased motion not only in the target segment but also the adjacent segments. During the ventral approach and the decompression of the spinal canal the anterior longitudinal ligament, major parts of the ventral annulus and the posterior longitudinal ligament at the target level are dissected. This seems to have a destabilizing effect spanning several segments during FE loading but does not show a clear influence in LB and AR.

**Fig. 1**



**Fig. 1:** Median range of motion (ROM) and neutral zone of each motion segment during FE (A), LB (B) and AR (C). Errors bars represent range of ROM. Significant differences (p < 0.05) in ROM are denoted with an asterisk.

## V 35

**Image-guided screw placement in the upper cervical spine – analysis of accuracy and safety of different fluoroscopic techniques**

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**Objective:** Due to the complex anatomy of the upper cervical spine, screw placement in C1 and C2 might become challenging with a high risk of intraoperative complications. In this study, we assessed the accuracy and safety of C1 and C2 screw placement using one of three techniques: standard biplanar fluoroscopy (SBF) vs. navigated screw placement with 3D fluoroscopy (n3DF) or robotic cone-beam CT (nRCC) guidance.

**Methods:** The study group comprised all consecutive cases with image-guided posterior screw placement in C1 and/or C2 treated in our institution between 2009 and 2022. Preoperative CT scans were analyzed regarding anatomic characteristics of the vertebrae, as well as an optimal screw position (with longest possible intraosseous course) using 3D reconstruction with a navigation software for all cases. The accuracy of screw placement was assessed in the postoperative CT scans. The rates of screw-related complications, intraoperative screw repositions, and screw revision surgeries were recorded.

**Results:** By June 2022, 80 image-guided surgeries for screw placement in the upper cervical spine were included (n=41/28/11 for SBF/n3DF/nRCC; mean age: 57.9 years; 60% males). There were no cases of new neurologic deficits or vertebral artery injury related to screw malposition. Regarding the results of C1 screws (n=93), navigated screw placement showed higher accordance with the modulated optimal screw position (90.7% vs 83.3%, p<0.0001), lower extent of cortical breaching (0.4 vs 1.4 mm, p=0.003), and no screw revision surgery (0% vs 9.7%, p=0.035) as compared to SBF-guided technique. In the C2 screw subgroup (n=97), navigated screws were also superior with regard to the optimal screw position (84.6% vs 50%, p<0.0001) and cortical breaching rate (12.8% vs 34.5%, p=0.019) compared to the non-navigated screws. When comparing both techniques of navigation-guided screw placement, there was a lower rate of cortical breach (C1: 18.8% vs 34.8%, p=0.347; C2: 7.1% vs 32%, p=0.119), narrowing of the vertebral canal (C1: 0% vs 4.3%, p=1.000; C2: 0% vs 4.0%, p=1.000), and intraoperative screw revision (C1: 0% vs 4.3%, p=1.000; C2: 0% vs 8.0%, p=0.528) in the nRCC- than in n3DF-navigated cases.

**Conclusions:** Intraoperative navigation yields higher accuracy and safety for screw placement in the upper cervical spine. Recent improvements of intraoperative cone-beam CT with robotic image-assistance technique provide better image quality in the operation room, allowing surgeons to further minimize surgery-related risks.

## V 36

**Do we risk the development of pseudarthrosis in spinal fusion surgery by using tranexamic acid? An *in vitro* study of the effect on human osteoblasts**

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**Introduction:** Tranexamic acid (TXA) is increasingly used systemically and locally to control bleeding in the context of orthopedic emergency and elective surgery. Partially, administration is continued systemically postoperatively to minimize the risk of rebleeding. However, no studies have been conducted to date to determine whether TXA has effects on human bone turnover and regeneration. Specifically, during spinal fusion surgery, a negative effect of TXA on bony consolidation would potentially increase the rate of pseudarthrosis. Therefore, the hypothesis of the present study was that TXA would have a concentration-dependent negative effect on vitality, alkaline

phosphatase (AP) activity, and bone regeneration-related gene expression of human osteoblasts (Ob).

**Material and Methods:** To study this, the effect of TXA on human Ob was investigated in a standardized cell culture experiment. Ob were obtained from samples of human bone sections, each performed during endoprosthesis joint replacement at the knee joint (n=10). Cells were cultured in a 24-well cell culture plate for up to 21 days and treated with different TXA concentrations (0.001 mg/ml, 0.01 mg/ml, 0.1 mg/ml, 1 mg/ml, 10 mg/ml) for the entire cultivation period (long-term treatment) or initially for 48 h (short-term treatment). Untreated osteoblasts served as controls. After 1, 7, 14 and 21 d, cells were analyzed by qRT-PCR (Delta-Delta Ct method), alkaline phosphatase (AP) activity and cell viability (PrestoBlue). Statistical data were compared and analyzed using a Wilcoxon test or a Mann-Whitney-U test.

**Results:** Cell viability was not negatively affected regardless of TXA concentration throughout the cultivation period (short- and long-term treatment). Until a concentration of 0.1 mg/ml, TXA had no negative effect on the expression of genes important for bone regeneration (AP, collagen 1, osteopontin, osteocalcin, osteonectin, RUNX 2). High TXA concentration (1 and 10 mg/ml) up to day 7 resulted in predominantly enhanced gene expression, while decreased gene expression was observed after 21 days. Thereby, the enhanced expression of osteonectin was most impressive until day 14 (p<0.05). For AP activity, a negative effect was observed at high TXA concentrations after 21 days (0.1 mg/ml vs. 10 mg/ml, p<0.05).

**Conclusion:** Contrary to the hypothesis, a positive effect on bone regeneration-related gene expression of human Ob under high-concentration TXA treatment was seen in the therapeutically relevant time window up to 14d. Thus, short-term perioperative use of TXA during fusion surgery does not seem to have a direct negative effect on the targeted bone regeneration. On the contrary, short-term perioperative use of TXA might even have a positive effect on the targeted fusion. To verify the present data, further *in vitro/in vivo* studies (e.g., osteoclast/Ob co-cultures, protein analyses, animal models, etc.) are required.

## V 37

**Future expectations in spinal fusion – a nationwide projective analysis**

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**Introduction:** Spinal fusion procedures are established in the treatment of degenerative spinal diseases with an increasing rate of surgery within the last decades in industrialized countries. The purpose of this study was to analyze age and sex related changes in the future to project the expected burden of spinal fusion procedures until 2060 in an aging population.

**Methods:** Comprehensive nationwide data provided by the Federal Statistical Office of Germany was used to quantify spinal fusion rates as a function of age and gender. Projections were compared using Poisson regression models as well as exponential smoothing and autoregressive integrated moving average models on historical procedure rates from 2005 to 2019 in relation to official population projections from 2020 to 2060, and the most accurate model was chosen.

**Results:** The incidence rate of spinal fusion is projected via exponential smoothing modeling to increase by around 19 % to 102.51 per 100,000 inhabitants [95% CI 15.98–189.04], leading to a projected total number of 81,692 spinal fusions in 2060 [95% CI 12,734– 150,650] with the highest increase modeled in patients over 80 years of age, for both men and women. While the incidence rate of dorsal spondylodeses remains relatively stable with 35.68 per 100,000 inhabitants [95% CI 14.25–49.93] and the incidence rate of ventral spondylodeses decreases by around 26 %

to 22.52 per 100,000 inhabitants [95% CI 0–45.04], the incidence rate of dorsoventral spondylodeses increases by around 128 % to 44.31 per 100,000 inhabitants [95% CI 35.23–49.71], leading to a projected total number of 35,310 of dorsoventral spondylodeses in 2060 [95% CI 28,075–39,615] in 2060.

**Discussion:** The present study predicts a relatively stable number of spondylodeses performed in Germany within the next 40 years. However, the shift to an older age as well as the huge increase of spondylodeses performed in male and female patients over 80 years of age will challenge spinal surgeons and put an enormous burden on the German health care system. Given the known risk factors in the operative treatment of elderly patients, the development of inter-institutional high-age-related protocols is imminent to optimize the perioperative therapy of elderly patients in the future.

### V 38

#### Bone turnover markers in the preoperative assessment of bone quality – a prospective investigation of bone microstructure and advanced glycation endproducts in lumbar fusion patients

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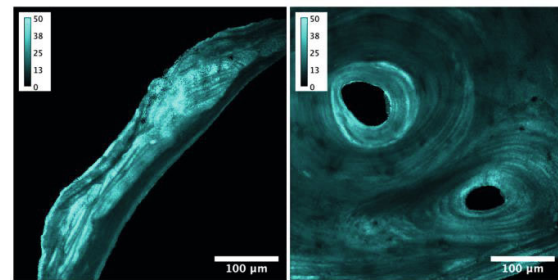
**Background:** Effective tools to evaluate bone quality preoperatively are scarce and the standard method to determine bone quality requires an invasive biopsy. Therefore, a non-invasive, and preoperatively available method for bone quality assessment would be of clinical value. The aim of our study is to investigate the associations of bone formation marker, serum bone alkaline phosphatase (BAP), and bone resorption marker, urine collagen cross-linked N-telopeptide (uNTX) to 1) volumetric bone mineral density (vBMD), 2) fluorescent advanced glycation endproducts (fAGEs) and 3) bone microarchitecture.

**Methods:** A cross-sectional analysis using prospective data of patients undergoing lumbar spinal fusion was performed. BAP and uNTX were preoperatively collected. Quantitative computed tomography (QCT) was performed at the lumbar spine (vBMD $\leq$ 120mg/cm<sup>3</sup> osteopenic/osteoporotic). Bone biopsies from the posterior superior iliac spine were obtained and evaluated with multiphoton fluorescence microscopy for fAGEs and microcomputed tomography ( $\mu$ CT) for bone microarchitecture. Correlations between BAP/uNTX to 1) vBMD, 2) fAGEs and 3)  $\mu$ CT parameters were assessed with Spearman's  $\rho$ . Receiver operating characteristic (ROC) analysis evaluated BAP and uNTX as predictors for osteopenia/osteoporosis. Multivariable linear regression models with adjustments for age, sex, BMI, race and diabetes mellitus determined associations between BAP/uNTX and fAGEs.

**Results:** 127 prospectively enrolled patients (50.4% female, 62.5 years, BMI 28.7 kg/m<sup>2</sup>) were analyzed. uNTX ( $\rho=-0.331, p<0.005$ ) and BAP ( $\rho=-0.245, p<0.025$ ) decreased with cortical fAGEs, and uNTX ( $\rho=-0.380, p<0.001$ ) decreased with trabecular fAGEs. BAP and uNTX revealed no significant correlation with vBMD. ROC analysis for BAP and uNTX discriminated osteopenia/osteoporosis with an AUC of 0.477 and 0.561, respectively. In the multivariable analysis, uNTX decreased with increasing trabecular fAGEs after adjusting for covariates ( $\beta=0.923; p=0.031$ ).

**Conclusion:** This study demonstrated an inverse association of bone turnover markers and fAGEs. Both uNTX and BAP could not predict osteopenia/osteoporosis in the spine. uNTX reflects collagen characteristics and might have a complementary role to vBMD, as a non-invasive tool for bone quality assessment in spine surgery.

Fig. 1



### V 39

#### Influence of spinal muscle mass, bone density and frailty on the success of dorsal spondylodesis in low-impact lumbar spine fractures

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**Objective:** Age-related loss of bone and muscle mass are signs of frailty and associated with increased risk of falls and consecutive vertebral fractures. Management often necessitates fusion surgery. We determine the impact of sarcopenia and bone density on implant failure (IF) and complications in patients with spondylodesis due to low-impact vertebral fractures.

**Methods:** Patients diagnosed with low-impact fractures between 2011 and 2020 were included in our study. The skeletal muscle area (SMA) was measured at the third lumbar vertebra (L3) level using axial CT images. SMA z-scores were calculated for optimal height and body mass index (BMI) adjustment (zSMAHT). Loss of muscle function was assessed by measurement of myosteatosis (skeletal muscle radiodensity, SMD) on axial CT scans. Bone mineral density (BMD) was determined at L3 in Hounsfield Units (HUs).

**Results:** 68 patients with low-impact vertebral fractures underwent instrumentation in 202 segments (mean age 73.7 $\pm$ 7.9 years, 60.3% female). The median time of follow-up was 14.1 $\pm$ 15.5 months. Sarcopenia was detected in 28 patients (47.1%), myosteatosis in 45 patients (66.2%), and osteoporosis in 49 patients (72%). The presence of sarcopenia was independent of chronological age ( $p=0.77$ ) but correlated with BMI ( $p=0.005$ ). zSMAHT was significantly lower in patients suffering from IF ( $p=0.0092$ ). Sarcopenia (OR 4.511, 95% CI 1.459–13.04,  $p=0.0092$ ) and osteoporosis (OR 9.50, 95% CI 1.497 to 104.7,  $p=0.014$ ) increased the likelihood of IF. Using multivariate analysis revealed that zSMAHT is significantly related to IF occurrence ( $p=0.004$ ).

**Conclusion:** Herein, we established sarcopenia-obesity as the main determinant for the occurrence of IF after instrumentation for low-impact fractures. To a lesser degree, osteoporosis was associated with impaired implant longevity. Therefore, measuring SMA and BMD using axial CT of the lumbar spine might help preventing IF in spinal fusion surgery by early detection and treatment of sarcopenia and osteoporosis.

### V 40

#### Comparative outcome of different treatment options for fragility fractures of the sacrum (FFS)

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**Background:** FFS have been detected more and more frequently in recent times, and the incidence will continue to increase due to increasing life expectancy. The aim of this study was to compare the feasibility and clinical outcome of conservative, interventional and surgical treatment of FFS.

**Material/Methods:** Retrospectively, 292 pat. (276 women, 16 men) with confirmed FFS were followed up over a period of 5 years. The age of the women was  $\bar{O}$  81.2 (58–99) and that of the men  $\bar{O}$  78.1 (76–85) years. The immobilizing pain was quantified using VAS. A fracture classification was carried out considering X-rays, CT and MRI examinations. An interdisciplinary case conference determined the individual treatment concept with classification into conservative, interventional or surgical treatment. During the course, the development of pain using VAS, independence using HBI, complications and patient satisfaction were documented.

**Results:** Pat. with a pain level of  $\leq 5$  benefited from the conservative therapy measures, with pain levels  $> 5$  significantly delaying the development of mobility. After sacroplasty, the pain reduced significantly, which enabled a significant improvement in mobility in the short term without any significant difference being found between the vertebra- (VSP), balloon- (BSP), radiofrequency- (RFS) and cement sacroplasty (CSP). Cement augmentation was performed well in all pat. Asymptomatic leakage was found in 20% after VSP and 12.2% after CSP. The planned osteosynthesis could be carried out as planned. In terms of pain reduction and mobilization, the pat. benefited from osteosynthesis, although more complex fracture types with lumbopelvic stabilization performed took longer. In 8 of the 59 operated pat, material loosening developed that did not require revision. Overall, there was no death during the hospital stay. Mortality after 12 months was 21.7% for the conservative, 8.4% for the interventional and 13.6% for the surgical therapy group; the differences are significant. In pat. in the conservative therapy group who were difficult to mobilize due to the pain, the mortality increased to 24.3%. In the course of 24 months, the pat. achieved the best independence after sacroplasty using the HBI with approx. 80 score points. At 12 and 24 months, subjective satisfaction with the therapies was best after sacroplasty, followed by osteosynthesis and conservative measures.

**Conclusions:** Pat. with FFS with a low level of pain benefit from conservative therapy measures, whereby complications and mortality increase significantly in the case of persistent immobilizing pain. Pat. with an unacceptable level of pain in non-dislocated fractures benefit significantly from sacroplasty in terms of short-term and sustained pain reduction. Pat. with unstable and displaced fractures should be operated on promptly.

#### V 41

##### Thoracic pedicle screw anchorage using the modified slide vs. conventional technique for screw placement

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**Introduction:** Thoracic pedicle screw placement remains challenging and confers a significant risk of screw misplacement due to the more complex and variable thoracic pedicle anatomy. Vialle et al. proposed a pedicle screw insertion technique named "slide technique" to increase safety and accuracy of thoracic pedicle screw placement. While the conventional insertion technique involves creation of a small dorsal cortical pilot hole at

the entry point, the slide technique involves decortication of the posterior cortex of the transverse process. The latter allows to identify the exact entry to the pedicle more easily by direct visualization and to use the anterior cortex of the decancelled transverse process as a slide to ensure correct pedicle probe insertion. However, pedicle screw anchorage after screw placement using the slide technique has not been evaluated yet. The purpose of this study was to biomechanically compare thoracic pedicle screw anchorage after screw placement with the modified slide (MS) technique and the conventional technique.

**Materials and Methods:** Fifteen fresh frozen human thoracic vertebrae (T5-T11; mean age:  $67.5 \pm 3.7$ ; mean BMD:  $111.0 \pm 22.1$ ) were used for this study. For pairwise comparisons, one randomly selected pedicle of each vertebra was instrumented using the MS-technique, while the contralateral pedicle was instrumented using the conventional technique for screw placement. Each pedicle screw was subjected to cyclic cranio-caudal loading with an initial load ranging from -50 N to +50 N and with stepwise increasing compressive loads (5 N every 100 cycles) until screw loosening. After screw loosening, pullout testing was performed to evaluate the residual fixation strength of each screw within the vertebra.

**Results:** Thoracic pedicle screws inserted using the MS technique resisted a significantly lower number of load cycles until loosening than screws inserted using the conventional technique ( $7987.9 \pm 1871.9$  vs.  $9927.0 \pm 2352.5$ ,  $p < 0.01$ ). These numbers of load cycles correspond to load magnitudes at loosening of  $442.3 \pm 94.0$  N vs.  $545.7 \pm 177.4$  N, respectively ( $p < 0.01$ ). Maximum pullout force of loosened screws did not significantly differ between the two insertion techniques ( $511.3 \pm 205.4$  N vs.  $544.7 \pm 177.4$  N,  $p = 0.52$ ).

**Discussion:** Our data indicate that screw anchorage of thoracic pedicle screws placed with the MS technique is lower than that of screws placed with the conventional technique. However, the load magnitude at loosening is still higher than that reported for cement augmented lumbar pedicle screws. Therefore, the MS technique might be useful to facilitate correct thoracic pedicle screw placement not only but particularly in difficult anatomical situations, such as small pedicles and/or spinal deformity.

#### V 42

##### Vancomycin and sodium hypochlorite – are they really save in spine surgery?

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**Introduction:** Topical use of vancomycin and sodium hypochlorite in septic spine surgery is very common. However, drug-induced tissue damage to the dura has not been studied, but could potentially cause infections intradurally by disrupting the blood-brain barrier. In addition, drug transfer to intradural could be neurotoxic. Therefore, we aimed to investigate the effects of topically used vancomycin and sodium hypochlorite on the tissue of the spinal dura in-vitro.

**Material and Methods:** Time dependent (2 – 240min) relative mass transfer of vancomycin (1, 10, 100mg/ml) through bovine dura mater samples was calculated by dividing the observed concentrations (determined by high resolution liquid-chromatography mass spectrometry (HRMS)) of the acceptor and those of the donor compartment in an in-vitro model. To investigate the non-diffusion limited effects, thin tissue sections were cut perpendicular to the dura's surface, ensuring drug

exposure to all dural layers. Using spatiotemporal Second-Harmonic-Generation (SHG) imaging, we analyzed drug-induced tissue changes roughly between minute 5 and 50 at 2-minute intervals, focussing on dimensional changes of thin section height and width as well as a degeneration of collagen fibers as indicated by the SHG-signal intensity itself. On top of this, protein release into dura perfusates was analyzed quantitatively using the Bradford assay and by SDA-PAGE with silver-staining together with permeability of the treated dura samples based on 3'-(p-aminophenyl) fluorescein (APF) diffusion after sodium hypochlorite or vancomycin treatment.

**Results:** HRMS analyses showed that a low relative but exposition time and concentration dependent (each  $p < 0.001$ ) rate (<5%) of the applied vancomycin passed the dura, especially in concentrations of 1 and 10 mg/ml. Depending on the applied vancomycin concentration in the donor compartment, approximately between 39 µg/mL and 480 µg/mL vancomycin was found in the acceptor compartment. From a spectroscopic point of view, sodium hypochlorite and vancomycin lead to a swelling in width associated with an overall loss of SHG intensity. Both substances lead to increased protein loss from the dura preparations. However, dura-permeation of APF was only detected after vancomycin treatment.

**Discussion:** We identified sodium hypochlorite and vancomycin as potentially damaging agents of the dura mater tissue. Our study demonstrated that both can lead to protein release and especially vancomycin diffuses through the dura mater. In-vivo this could lead to potential neurotoxic consequences. Besides this, the weakening of the blood-brain barrier could also result in dissemination of infection to the cerebrospinal fluid. Despite the results were derived in an in-vitro setting and cannot be fully transferred to in-vivo condition, we suggest irrigation with saline after that with sodium hypochlorite. Additionally, direct vancomycin powder placement on the dura should be avoided.

Fig. 1

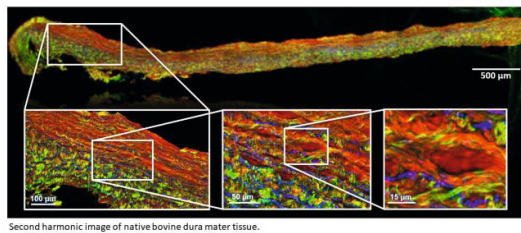
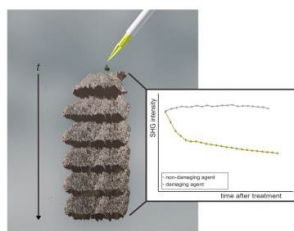


Fig. 2



V 43  
**Influence of age and pelvic incidence on cervical sagittal alignment parameters in adult scoliosis**

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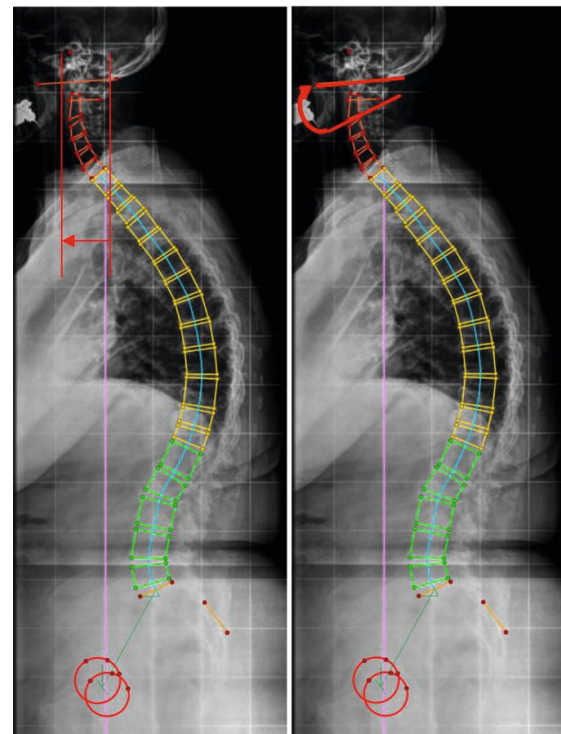
**Introduction:** Cervical alignment parameters can be divided two categories: occipito-cervical and sub-axial parameters. These parameters vary according to age and spino-pelvic organization in healthy adults. The objective of this retrospective cross-sectional study was to describe cervical parameters as a function of age and pelvic incidence (PI) in non-pathologic subjects and to compare them to patients with scoliosis to analyze cervical compensation mechanisms in adult spinal deformity.

**Methods:** EOS radiographs of 478 subjects (327 females and 151 males) were divided into 235 non-pathologic and 243 scoliotic subjects. Occipito-cervical parameters were: McGregor-C1, McGregor-C2, C1-C2 and occipito-C2, -C3, -C4 angles. The cervico-thoracic inflexion point (CTIP) was determined. Subaxial parameters were: C2-C7, C2-apex (cranial arc) and apex-CTIP (caudal arc) lordosis, C7 and T1 slope. Value distributions were analysed using a Bayesian inference (significance  $Pr > 0,975$  or  $Pr < 0,025$ ). Non-pathologic and scoliotic cohorts were compared while adjusting on age (40-60 years ; >60 years) and PI (<45° ; 45-60° ; >60°).

**Results:** Among occipito-cervical parameters, there was no significant change of the McGregor-C1 angle. The McGregor-C2 angle was significantly larger in the scoliotic group ( $Pr = 0,0029$ ), with an influence of age ( $Pr = 0,023$ ), without influence of PI. C1-C2 lordosis was significantly larger in the scoliotic group ( $Pr < 0,0007$ ), without effect of age or PI. C2-C7 lordosis was larger in scoliosis ( $Pr < 0,025$ ) with an effect of age and PI ( $Pr < 0,025$ ). Cranial arc lordosis increased significantly in scoliosis ( $Pr > 0,999$ ), without effect of age or PI. Caudal arc lordosis didn't differ between non-pathologic and scoliotic subjects, but this parameter increased significantly with age ( $Pr < 0,0007$ ). C7 and T1 slope increased with age ( $Pr < 0,0012$ ) without effect of deformity or PI.

**Conclusion:** This observational study evidenced adaption phenomena of cervical alignment in adult scoliosis adjusted on age and PI. Caudal arc cervical lordosis mainly increases physiologically with age as a response to increasing thoracic kyphosis. An additional effect is noticed in adult scoliosis, where subaxial cranial arc lordosis and occipito-cervical parameters increase in terms of head extension as a compensation mechanism to maintain horizontal gaze, where patients present more global anterior malalignment.

Fig. 1



## V 44

**Impact of the level of the lowest instrumented vertebra in surgical correction of adolescent idiopathic scoliosis on correction of the minor curve**\*M. Koniczny<sup>1</sup>, P. Denz<sup>2</sup>, J. Windolf<sup>2</sup>, M. Prost<sup>2</sup><sup>1</sup>ATOS Viktoriaklinik, Wirbelsäulenchirurgie, Bochum, Deutschland<sup>2</sup>Universitätsklinikum Düsseldorf, Klinik für Orthopädie und Unfallchirurgie, Düsseldorf, Deutschland

**Introduction:** According to the Lenke classification, scoliotic curves can be classified as structural or non-structural. If a selective fusion is performed, the non-structural curves are not instrumented. Choosing the lowest instrumented vertebra (LIV) and the impact of different levels of the LIV on the correction of the non-instrumented minor curve in the frontal profile and on the sagittal balance is still under debate.

**Methods:** We enrolled 53 consecutive patients with an idiopathic adolescent scoliosis who have been treated by posterior instrumented fusion in a retrospective investigation. Impact of the level of the LIV with regard to distance to end vertebra (EW), to the stable vertebra (StV), to the sagittal inflection point (IP) and to the apex of the lumbar lordosis on the correction of the minor curve was analyzed.

We performed a one way ANOVA analysis. Statistical analysis was performed by SPSS 25.

**Results:** Distance of LIV to EW was only significant with regard to correction of the minor curve if it was more than 5 levels (i.e. vertebral bodies) ( $p < 0.001$ ).

Distance of LIV to StV was only significant with regard to correction of the minor curve if it was more than 4 levels (i.e. vertebral bodies) ( $p < 0.01$ ).

Distance of LIV to IP was significant with regard to correction of the minor curve if it was more than 2 levels (i.e. vertebral bodies) ( $p < 0.01$ ).

Distance of LIV to the apex of the lumbar lordosis was not significant with regard to correction of the minor curve (i.e. vertebral bodies) ( $p > 0.05$ ).

**Conclusions:** In our group of patients choosing of an LIV that was more than 2 levels higher or lower than the sagittal inflection point showed a significant higher correction of the minor curve. We therefore recommend to keep that distance when LIV is chosen.

Parameters of the frontal profile did only show an impact that was significant if very large distances (5 or more levels) were compared.

These results seem to support the assumption, that the sagittal profile shall also be analyzed when surgical correction of an idiopathic adolescent scoliosis is planned.

## V 45

**Paraspinal musculature impairment is associated with spinopelvic and spinal malalignment in patients undergoing lumbar fusion surgery**\*M. Müller<sup>1,2</sup>, H. Haffer<sup>1,2</sup>, M. Moser<sup>2,3</sup>, E. Chiapparelli<sup>2</sup>, Y. Dodo<sup>2</sup>, D. Adl Amini<sup>1,2</sup>, J. A. Carrino<sup>4</sup>, E. T. Tan<sup>4</sup>, J. Shue<sup>2</sup>, J. Zhu<sup>5</sup>, A. A. Sama<sup>2</sup>, F. P. Cammisia<sup>2</sup>, F. P. Girardi<sup>2</sup>, A. P. Hughes<sup>2</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Centrum für Muskuloskeletale Chirurgie (CMSC), Berlin, Deutschland<sup>2</sup>Hospital for Special Surgery, Spine Care Institute, New York City, NY, USA<sup>3</sup>Luzerner Kantonsspital, Klinik für Neurochirurgie und Interdisziplinäre Wirbelsäulenchirurgie, Luzern, Schweiz<sup>4</sup>Hospital for Special Surgery, Department of Radiology and Imaging, New York City, NY, USA<sup>5</sup>Hospital for Special Surgery, Biostatistics Core, New York City, NY, USA

**Introduction:** The concept of sagittal spinal malalignment is well established in spinal surgery, however, the effect of musculature on its development has not been fully considered. Furthermore, the positioning of the pelvis is mostly seen as compensatory and not necessarily a possible cause of sagittal imbalance. The influence of the paraspinal muscles on spinopelvic and spinal alignment has not yet been elucidated, which was the aim of the present study.

**Material and Methods:** A retrospective review of a dataset of patients undergoing lumbar fusion surgery between 2014 and 2021 at a single academic institution was performed. A MRI-based quantitative assessment of the cross-sectional area (CSA), the functional cross-sectional area (fCSA) and the amount of intramuscular fat (FAT) was conducted. The percentage of fat infiltration (FI) was further calculated. The regions of interest included the psoas muscle and the posterior paraspinal muscles (PPM) at the L4 level. The left and right side of the muscle groups were summarized and normalized by the patient's height ( $\text{cm}^2/\text{m}^2$ ). Lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), pelvic incidence (PI) and C7 sagittal vertical axis (SVA) were determined on standing radiographs. The Spearman correlation coefficient was determined for the spinopelvic and muscle parameters. Multiple linear regression models with age, sex, gender, LL, PT, SS and SVA set as independent variables were established to determine the association with muscular parameters.

**Results:** A total of 150 patients (53.3% female) were included in the final analysis with a median age of 65.6 years and a median BMI of  $28.2 \text{ kg/m}^2$ . Significant positive correlations were observed between PT ( $p = 0.327$ ), SVA ( $p = 0.256$ ) and PI ( $p = 0.202$ ) and the FIPPM. Significant negative correlations were detected for the PT and the fCSA<sub>PPM</sub> ( $p = 0.202$ ) and PT and the fCSA<sub>psoas</sub> ( $p = 0.191$ ). Furthermore, a negative correlation was seen for PI and SVA and FI<sub>psoas</sub>. PT ( $\beta = 0.187$ ;  $p = 0.006$ ), SVA ( $\beta = 0.155$ ;  $p = 0.035$ ), age ( $\beta = 0.468$ ;  $p < 0.001$ ) and sex ( $\beta = 0.235$ ;  $p < 0.001$ ) significantly predict FI<sub>PPM</sub> (corrected  $R^2 = 0.393$ ) as independent variables.

**Conclusion:** The study demonstrated the potential role of the posterior paraspinal muscles and psoas muscle on the pelvic retroversion and elucidated the relation to sagittal spinal malalignment. We propose that the increasing FI<sub>PPM</sub>, representing loss of muscular strength, leads to an increased pelvic retroversion and thus might be the initiating point for the development of the sagittal imbalance. These findings might challenge the well-known theory of increased pelvic retroversion being a compensatory mechanism for sagittal spinal balance. Thus, muscular weakness might be a factor involved in the development of sagittal spinal malalignment.

## V 46

**Comparison of spinopelvic alignment and Roussouly types between children, adolescents and adults**\*Y. P. Charles<sup>1</sup>, V. Lamas<sup>2</sup>, B. Ilharreborde<sup>3</sup>, G. Riouallon<sup>4</sup>, F. Solla<sup>4</sup>, E. Ferrero<sup>5,6</sup>, B. Blondel<sup>7</sup>, E. A. Sauleau<sup>8</sup>, S. Pesenti<sup>7</sup><sup>1</sup>Hôpitaux Universitaires de Strasbourg, Service de Chirurgie du Rachis, Strasbourg, Frankreich<sup>2</sup>Hôpitaux Universitaires de Strasbourg, Service de Chirurgie du Rachis, Straßburg, Frankreich<sup>3</sup>Hôpital Robert Debré, Paris, Frankreich<sup>4</sup>Hôpital Lenval, Nice, Frankreich<sup>5</sup>Clinique Jean Villar, Bruges, Belgien<sup>6</sup>HEGP, Paris, Frankreich<sup>7</sup>CHU La Timone, Marseille, Frankreich<sup>8</sup>Hôpitaux Universitaires de Strasbourg, Département de Santé Publique/épartement de Santé Publique, Straßburg, Frankreich

**Introduction:** The Roussouly classification was validated for adults. Alignment types may vary during growth. The aim of this retrospective cross-sectional study to describe spinopelvic alignment types by Pelvic Incidence (PI) and age to compare the Roussouly classification between pediatric and adult populations.

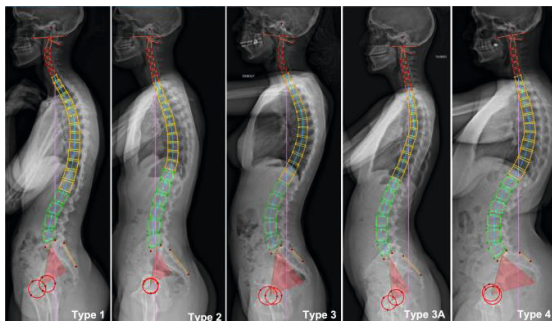
**Methods:** Radiographs of 1706 non pathologic individuals (5–49 years) were analyzed. Individuals  $\leq 19$  years were stratified by chronological age and skeletal maturity (triradiate cartilage, Risser), and compared to adults. Global and spinopelvic alignment parameters were assessed. Roussouly Types 1, 2, 3, 3A (anteverted pelvis) and 4 were determined. The distribution of parameters was analyzed by Bayesian inference. The relationship between PI and age by Roussouly type was modeled by linear regression.

**Results:** The Sagittal Vertical Axis C7 decreased during growth and was significantly smaller in adults (20–34 years) ( $Pr > 0.99$ ). Thoracic kyphosis and lumbar lordosis increased during growth and were larger in adults ( $Pr < 0.025$ ). Lordosis increased mainly in the cranial arch ( $Pr < 0.025$ ). PI and pelvic tilt increased during

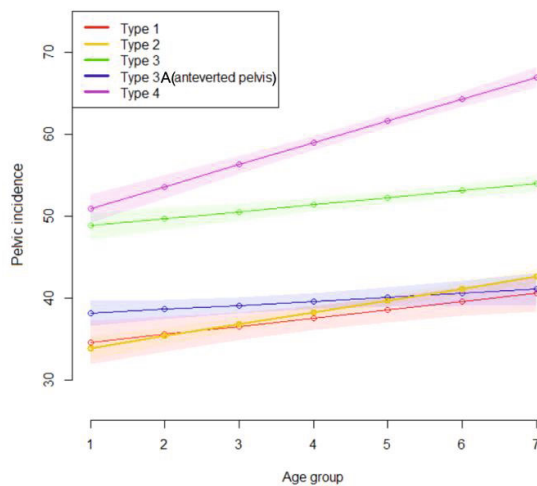
growth and were larger in adults ( $Pr < 0.025$ ). In children and adolescents,  $PI < 45^\circ$  represented the largest proportion, significantly larger compared to adults ( $Pr > 0.99$ ). Proportions of Roussouly Types 1 and 2 were similar throughout ages. Types 3 and 4 were rarer during the prepubertal period ( $Pr < 0.025$ ). The proportion of Type 3A was significantly higher in children and adolescents ( $Pr > 0.99$ ). Linear regression showed that Type 4 had the largest PI increase with age, with significantly higher curve slope compared to other types ( $Pr > 0.9999$ ). Types 3, 3A and 2 had similar slopes and lowest PI increase with age.

**Conclusion:** Global and spinopelvic alignment changed during childhood and adolescence, leading to different kyphosis and lordosis distribution compared to adults. Growth-related PI increase influenced Roussouly types with typical predominance of Type 3A in the pediatric population and larger PI increase in Type 4.

**Fig. 1**



**Fig. 2**



#### V 47

##### Preoperative PONV prophylaxis with dexamethasone is associated with increased wound revisions in the surgical management of neuromuscular scoliosis

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**Introduction:** The application of dexamethasone for perioperative prophylaxis of postoperative nausea and vomiting syndrome is an established method. Despite the advantages, cortisone application shows a tendency to develop wound infections and consecutive surgical wound revisions. In a population of cognitively impaired patients, the risk-benefit ratio of PONV versus surgical intervention and prolonged intravenous antibiotics needs to be assessed more carefully.

**Methods:** In a retrospective cohort study, all patients with secondary scoliosis under 18 years of age who underwent spinal instrumentation were included and analysed with regard to the application of dexamethasone perioperatively and the development of wound infections with the need for surgical revision and the length of hospital stay (secondary outcome). Intravenous application of dexamethasone was done preoperatively after decision of anaesthesia after careful assessment of PONV – risk.

**Results:** A patient cohort of  $n = 162$  patients (dexamethasone  $N = 30$ , control  $N = 132$ ) could be included with the above criteria. There were no statistically significant differences in demographic data (age, sex, weight, height, BMI) and patient characteristics (underlying disease, ASA, cognition, mobilisation). Similarly, there were no statistical differences in surgical care (type of surgery, duration of surgery, duration of anaesthesia), although there were absolutely more revision surgeries in the dexamethasone group. There was a statistically significant difference in increased wound revisions after intravenous application of dexamethasone (Dexa  $N = 6$ , 20%) vs control ( $N = 5$ , 4.5%,  $p = 0.007$ ).

**Discussion:** The increased incidence of wound infections in the dexamethasone group gives reason to critically evaluate the application of dexamethasone in the perioperative treatment of children with neuromuscular scoliosis. In our patient population, there is a tendency to apply dexamethasone in children who have already undergone surgery, so that there is a certain bias. Data from randomised studies on the influence of dexamethasone in the care of children with neuromuscular disorders are still lacking and should be urgently initiated against this background.

#### V 48

##### Quality-of-Life long-term outcomes after IONM-aided microsurgical resection of cervicothoracic intramedullary spinal cord tumors

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**Introduction:** IONM-aided microsurgical resection is the therapy of choice for cervical and thoracic intramedullary spinal cord tumors (IMSCTs). While neurological outcome has been multiply reported, the long-term outcome for quality-of-life (QoL) aspects is still unknown.

**Material/Methods:** We prospectively assessed 24 patients (m/f: 14/10, median age: 46 years) undergoing cervical/thoracic IMSCT surgery with intraoperative recording of muscular motor and somatosensory evoked potentials, Direct Wave and free-running electromyography. Detailed neurological status (incl. hand-force measurements and 9-Hole-Peg-Test), McCormick Score, modified JOA Score (mJOA) as well as QoL with regard to Physical/Mental Compound Short-Form-36 Health Survey Score (SF-36-P/MCS) and Barthel-Index (BI) was assessed pre- and immediately postoperatively as well as at long-term follow-up (median 16 months, range 12–45 months) and correlated with patients'/tumor characteristics.

**Results:** 63% of the tumors were ependymomas, 17% high-grade gliomas, 13% cavernomas and 7% hemangioblastomas. 42% of the tumors were located between the C1–C4-level, 7% between the C5–C7-level, 29% between the Th1–Th6-level and 22% below the Th7-level. Gross-total resection was accomplished in 83%. Preoperatively, motor deficits were present in 29%, sensory disturbances in 67% and gait ataxia in 33% of the patients; median McCormick Score was 1, median mJOA 16, mean SF-36-P-/MCS 46.4/43.5 and median BI 100 in the overall cohort. At last follow-up, 7% of the patients had a persistent deterioration in motor function, 63% in sensory function and 25% in gait function compared to the preoperative status; the overall cohort's median McCormick Score was 1, median mJOA 14, mean SF-36-P-/MCS 44.0/44.4 and median BI 100 with no significant differences compared to the preoperative status for each item. Rates for individual improvement/deterioration in QoL aspects were 67%/33% for SF36-PCS, 59%/41% for SF-36-MCS and 71%/29% for BI. Presence of a postoperative deterioration in motor function with persistence at last follow-up was the only significant risk

factor for a worse QoL long-term outcome (pSF36-MCS=0.02, rSF36-MCS=0.47; pSF36-PCS=0.01, rSF36-PCS=0.50; pBI<0.001, rBI=0.63).

**Discussion:** QoL aspects improve in more than half of the patients during long-term follow-up after microsurgical resection of cervicothoracic IMSCTs. Persistence of a postoperative deterioration in motor function is a significant predictor for a worse QoL long-term outcome.

#### V 49

##### Rapid intraoperative tumor detection with label-free stimulated Raman histology in spinal tumors

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**Introduction:** Rapid intraoperative histological tissue sample assessment is an essential tool that guides surgical decision making. While fresh frozen tissue samples and hematoxylin & eosin (H&E) staining are currently the gold standard, recent works have introduced machine learning based deep convolutional neural network (CNN) analysis of label-free stimulated Raman histology (SRH) samples as a simple, fast alternative for fresh frozen samples in cranial lesions, enabling the surgeon to acquire a result within minutes.[1,2] We recently developed a new CNN to distinguish tumor and non-tumor SRH-samples in intracranial lesions. This work aims to investigate whether this algorithm validated for intracranial tumors can be applied in spinal tumors as well.

**Methods:** Small human spinal tumor tissue samples (1-3mm<sup>3</sup>) for SRH were acquired parallel to the regular pathological assessment and squeezed onto a histological slide resulting in a flat tissue layer of max. 10 mm<sup>2</sup>. Random areas of 2x2 mm within the sample were chosen for SRH analysis and the CNN was run afterwards. The pathological diagnosis was made in a typical routine workflow. CNN-based predictions were compared to final pathological diagnosis.

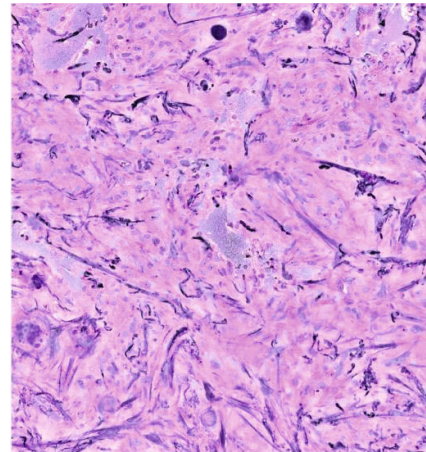
**Results:** 39 patients who underwent surgery for a spinal tumor were included. Of these, 105 SRH samples were generated. The CNN correctly classified 85.7% samples as tumor, 14% images were classified as "cannot exclude tumor", 0.3% was correctly labeled as "low quality" and no sample was incorrectly labeled as "no tumor".

**Discussion:** SRH based rapid intraoperative histological tissue sample assessment has great potential as a tool to generate fast histological feedback and to support intraoperative decision making. Together with the developed CNN this workflow can reliably detect the presence of tumor independent of tumor entity and conventional H&E frozen samples. Next to aiding the surgeon to achieve gross total resection, future developments could enable machine learning based tumor classification analogous to the classification CNN developed for intracranial lesions[1].

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**Fig. 1**



#### V 50

##### Parallel analysis of interleukin-6 and procalcitonin enables early diagnosis of postoperative wound infections after spine surgery (preliminary data from a prospective study)

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**Background:** Postoperative wound infections (PWIs) occur in 0.7 to 20% after spine surgery<sup>1</sup>. Current diagnostics for PWIs are based on clinical wound checks, laboratory chemistry parameters of infection, and, if highly suspected, cross-sectional imaging. However, radiation exposure and cost intensity of the latter demand reliable laboratory chemistry parameters. Usually, C-reactive protein (CRP) and leukocytes (Lk) represent the follow-up parameters. Recent evidence suggests that procalcitonin (PCT), interleukin-6 (IL-6), and tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) may indicate PWIs earlier. The aim of this prospective study is to observe CRP, Lk, PCT, IL-6, and TNF- $\alpha$  after open dorsal spine surgery.

**Methods:** Since 2020, CRP, Lk, PCT, IL-6 and TNF- $\alpha$  are determined on postoperative days 0,1,2,3,5 and 7 in patients with open dorsal instrumentation at a maximum care spine center of the DWG® (Level I). Patients with polytrauma, previous spondylodiscitis, and preoperative significantly elevated infection parameters are excluded. PWI is diagnosed intraoperatively and by the microbiological detection of germs. Patients are categorized into infectious group (INF) and non-infectious group (nonINF). Patient characteristics (age, sex, BMI, ASA score) and comorbidities are collected.

**Results:** To this date, 74 patients (29 men, 45 women, age: 64.8±15.3 years) have been included. 12 patients (16.2%) developed a PWI. Separate analysis of the parameters did not show significant differences. However, whereas in the INF group the peak for IL-6 was observed on postoperative day 1 and for PCT on postoperative day 3, the opposite was observed for both parameters in the nonINF group (Fig.1). The quotients of the groups were significantly different: IL-6<sub>day1</sub>/PCT<sub>day3</sub>: p=0.04; IL-6<sub>day1</sub>/PCT<sub>day5</sub>: p=0.049; IL-6<sub>day2</sub>/PCT<sub>day3</sub>: p=0.037; IL-6<sub>day2</sub>/PCT<sub>day5</sub>: p=0.04[41]. In the binary regression analysis (inclusion) of all separate infectious parameters, IL-6 revealed significant results on day 1,2 and 3 (p=0.003; R-square: 0.933). The difference in IL-6 from day 1 and 3 of the two groups was also significant (p=0.023). No independent risk factors were found in the regression analysis.

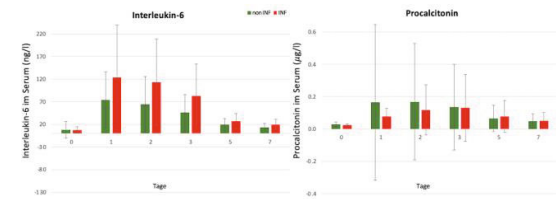
**Discussion:** In the preliminary results, IL-6 appears to be the most important laboratory chemical parameter for early diagnosis of PWIs. Especially in parallel observation of IL-6 and PCT and the opposite behavior of both parameters, the diagnosis of PWIs could already be possible on postoperative day 3. The final results will be evaluated after the inclusion of all 120 patients.



<sup>1</sup>Gelalis ID, Arnaoutoglou CM, Politis AN, Batzalexis NA, Katonis PG, Xenakis TA (2011): Bacterial wound contamination during simple and complex spinal procedures. A prospective clinical study. *Spine J* 11, 1042-1048.

Figure 1: Postoperative course of interleukin-6 and procalcitonin

Fig. 1



## V 51

### Shortening the time to diagnosis and therapy in spinal lesions of unknown malignancy

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**Introduction:** Malignant spinal lesions (MSL) often cause the initial symptoms of a previously unknown malignant disease (UMD). In addition to the spinal treatment, the focus is on rapid diagnosis confirmation and therapy initiation. The gold standard for confirming the diagnosis is histopathology (HP), which, however, takes up to 14 d for bone specimens. This study investigates the influence of supplementary intralesional spinal aspiration cytology (ISAC) on the time to diagnosis (TTD) and initiation of tumor-specific therapy (TTT). This study is supported by the German Spine Foundation.

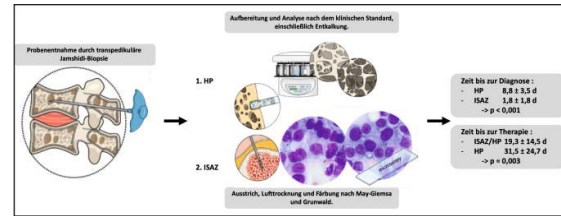
**Methods:** Retrospective analysis of patients with initial MSL for UMD and ISAC performed in addition to HP (ISAC/HP collective, n = 54) was performed. Bone marrow was aspirated intraoperatively from the MSL in citrate, stained according to May-Grunwald/Giemsa, and analyzed. HP was performed according to the standard (Fig.1). Concordance analysis and comparative analysis of TTD of ISAC and HP were performed. In addition, the comparative analysis of the TTT of the ISAC/HP collective was performed with a collective in which HP alone was performed (HP collective, n = 103). Concordance analyses were performed using Cohen's kappa and comparative testing was performed using Student's t-test. The significance level was  $p < 0.05$ .

**Results:** In the ISAC/HP collective, HP showed 6 benign lesions, 35 solid and 13 hematologic MSL. ISAC detected MSL in reference to HP with a sensitivity of 0.98, specificity of 0.71, and diagnostic certainty of 0.90. In addition, ISAC distinguished between hematologic and solid MSL with a concordance to HP of 94% (Cohen's kappa 0.88). The mean TTD of ISAC was  $1.7 \pm 1.8$  d and of HP was  $8.6 \pm 3.6$  d ( $p < 0.001$ ). In 13 patients, specific therapy could be initiated based on the ISAC and clinical, laboratory, and radiological parameters before the final HP report was available. The mean TTT in the ISAC/HP collective was  $19.3 \pm 14.5$  d and in the HP collective  $31.5 \pm 24.7$  d ( $p = 0.003$ ).

**Discussion:** ISAC has high sensitivity and specificity and high diagnostic certainty in identifying MSL. Solid and hematologic MSL are distinguished with high concordance to HP. TTD is significantly shortened by supplemental ISAC and specific therapy can be initiated in up to 24% of cases before receiving the final HP report. Overall, ISAC complementary to HP, compared with HP alone, significantly shortens TTT and should become the clinical standard.

**Fig1.:** Overview of the sample collection procedure and sample processing for histopathology (HP) and intralesional spinal aspiration cytology (ISAC). Complementary ISAC can achieve significantly shorter time to diagnosis ( $p < 0.001$ ) and time to therapy ( $p = 0.003$ ) compared to HP.

Fig. 1



## V 52

### AKT1E17K and NF2 mutations are the main driver events in spinal meningiomas and are associated with distinct tumor features

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**Introduction:** Meningiomas represent about one-third of all spinal tumors. To date, few is known about the molecular profile of spinal meningiomas (SM) and its clinical impact. In this study, we correlate tumor features with the molecular status in a well-characterized cohort of 50 SM patients.

**Methods:** SM samples from 39 females and 11 males were collected. We performed Next Generation Sequencing (NGS) using an assay that covers a large number of frequently mutated genes in meningiomas including *AKT1*, *KLF4*, *NF2*, *PIK3CA/PIK3R1*, *POLR2A*, *SMARCB1*, *SMO*, *SUFU*, *TRAF7*, and the *TERT* promoter. Furthermore, we correlated clinical and imaging data with the molecular tumor status.

**Results:** *AKT1E17K* mutations were detected in 15 (30%) and *NF2* mutations in 32 (64%) patients. In three cases (6%, two female and one male patients) no known driver mutations were found. *NF2*-mutant meningiomas occurred significantly more frequently in female patients (n = 30, 94%) than *AKT1*-mutant tumors (n=7,  $p = 0.0006$ ). A tumor location in the thoracic spine was significantly more common in *NF2*-mutant meningiomas (n = 25) than in their *AKT1*-mutant counterparts (n = 4,  $p = 0.0012$ ). In contrast, meningiomas harboring an *AKT1* mutation were predominantly located in the cervical spine (n = 11, 73.3%). Notably, 87% of *AKT1*-mutant meningiomas (n = 13) and 28% of *NF2*-mutant meningiomas (n = 14) arose ventrally to the spinal cord ( $p = 0.0101$ ). *NF2*-mutant meningiomas developed mainly in dorsal location to the spinal cord (n = 18, 56.2%). The histologic subtype of *NF2*-mutant meningiomas was variable (7 meningothelial, 14 psammomatous, 3 transitional, 5 fibrous), while all but one meningiomas harboring an *AKT1* mutation showed a meningothelial histology (93.3%,  $p = 0.0001$ ). Finally, none of the *AKT1*-mutant meningiomas showed calcifications in the MRI, whereas all calcified meningiomas (n = 17) were *NF2*-mutant ( $p = 0.0002$ ).

**Conclusions:** *AKT1* E17K and *NF2* mutations represent the main driver events in SM and are associated with distinct tumor features. *AKT1*-mutant meningiomas occur predominantly in male patients, originate in the cervical spine ventrally to the spinal cord, are almost exclusively associated with a meningothelial histology and exhibit no calcifications on MR imaging. *NF2*-mutant meningiomas are mainly representative in female patients, arise most frequently in the thoracic spine dorsally to the spinal cord, show variable histologic subtypes and are commonly calcified.

## V 53

**Intraoperative neuromonitoring of distal upper limbs' fine-motor function in cervical intramedullary spinal cord tumor surgery using spinal and muscular motor evoked potentials – the D-wave gap**\*S. Siller<sup>1</sup>, S. Duell<sup>1</sup>, J. Tonn<sup>1</sup>, A. Szelenyi<sup>1</sup><sup>1</sup>LMU Klinikum München, Neurochirurgische Klinik, München, Deutschland

**Introduction:** Gold standard for intraoperative assessment of motor pathways during cervical intramedullary spinal cord tumor (IMSCCT) surgery is performed with spinal (D-wave) and muscle MEPs. Especially D-wave is considered to safely monitor the function of the corticospinal tract (CST) caudally to the level of its placement. While it is well known that preserved D-wave predicts long-term lower limbs' motor outcome and ambulation (even with lost muscle MEPs), it is still unknown if D-wave can also safely monitor the integrity of the CST with regard to distal upper limbs' long-term motor function in this situation.

**Material/Methods:** We prospectively assessed 17 patients (m/f: 11/6, median age: 41 years) undergoing IMSCCT surgery above the C4/5-level with successful intraoperative recording of hand-muscle (hm) muscular MEPs and median-nerve (m)SSEPs, hand-muscle EMG (hmEMG) and epidurally D-wave (placed caudally to the surgical level so that at least the most rostrally located electrode safely covered the lower cervical segments). The following permanent IONM-alterations were considered significant: either loss or D-wave-amplitude decrement  $\geq 50\%$ , hmMEPs-amplitude decrement  $\geq 80\%$  or significant stimulation intensity increase, mSSEPs-amplitude reduction  $\geq 50\%$  / latency increase  $\geq 10\%$  as well as significant spontaneous activity of hmEMG. Distal upper/lower limbs' detailed motor function was assessed pre- and 8-12 weeks postoperatively as well as at long-term follow-up (median 15 months) and correlated with IONM-findings.

**Results:** 53% of the tumors were ependymomas, 29% gliomas, 12% cavernomas and 6% hemangioblastomas. 47% of the tumors were located above the C2/3-level and 53% between the C3/4- and C4/5-level. Gross-total resection was accomplished in 88%. Transient deterioration of hmMEPs resp. D-wave occurred in one patient each; these patients had a transient, but no permanent motor deficit. In the remaining patients, D-wave monitoring was stable/unremarkable. However, 5 of these patients postoperatively presented with a new motor deficit in distal upper limbs' muscle groups (with innervation of spinal cord levels caudally to the level of D-wave placement) which were persistent during long-term follow-up, while the lower limbs' motor function and gait were unaffected. In 4 of these 5 patients, critical and persisting hmMEPs/mSSEPs findings were present (despite immediate intraoperative corrective actions) resulting in a sensitivity of 80% and a specificity of 100% for those IONM-modalities.

**Discussion:** In high-cervical IMSCCT surgery, unimpaired D-wave findings reliably predicted preserved motor function of the lower limbs, however, did not sufficiently cover distal upper limbs' motor function, thus, giving rise to false-negative findings. Selective hmMEPs/mSSEPs-alterations have to be observed in this situation as those might predict distal upper limbs' detailed motor outcome.

## V 54

**Management of vertebral column lesions in Multiple Myeloma patients – a two-center experience of 450 cases**V. Hubertus<sup>1,2</sup>, M. Stangenberg<sup>3</sup>, L. Viezens<sup>3</sup>, C. von Bassenheim<sup>1</sup>, S. Schulz<sup>3</sup>, T. Keller<sup>4</sup>, D. Kaul<sup>5</sup>, P. Habbel<sup>6</sup>, I. W. Blau<sup>6</sup>, U. Keller<sup>6</sup>, M. Dreimann<sup>3</sup>, P. Vajkoczy<sup>1</sup>, \*J. S. Onken<sup>1</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Klinik für Neurochirurgie, Berlin, Deutschland<sup>2</sup>Charité – Universitätsmedizin Berlin, Berlin Institute of Health, Berlin, Deutschland<sup>3</sup>Universitätsklinikum Hamburg-Eppendorf, Unfallchirurgie und universitäres Wirbelsäulenzentrum, Hamburg, Deutschland<sup>4</sup>Charité – Universitätsmedizin Berlin, Biometrie und klinische Epidemiologie, Berlin, Deutschland<sup>5</sup>Charité – Universitätsmedizin Berlin, Radioonkologie, Berlin, Deutschland<sup>6</sup>Charité – Universitätsmedizin Berlin, Hämatologie und Onkologie, Berlin, Deutschland

**Objective:** In advanced stage, 70% of Multiple Myeloma (MM) patients suffer from vertebral column lesions. Indications for surgery are made with restraint because of an allegedly high complication rate. Structured data assessing indications and different types of spine surgery in MM patients is lacking. The aim of this study is to present such clinical data of a large multicentric cohort of MM patients suffering from vertebral column lesions.

**Methods:** Patients with vertebral column lesions due to MM were enrolled in this study at two academic oncological centers between 2005-2020. Data sets were retrospectively assessed regarding epidemiological, clinical, oncological, treatment and outcome data. Surgical data included surgical technique, duration of surgery and complications. The spinal instability neoplastic score (SINS) of every vertebral lesion was assessed. Ethical approval (EA4/063/20) was granted.

**Results:** 450 patients were enrolled in this study, suffering from 3621 vertebral column lesions. Median age at admission was 67 years. 89% suffered from vertebral pain and 17% from neurological deficits. 68% (n=308) of the patients received surgery, of whom 35% (n=108) received kypho- or vertebroplasty+/-decompression, and 65% (n=200) instrumented spine surgery. Of these, 60% (n=119) received posterior decompression+fusion (47% percutaneous), 6% (n=13) anterior fusion+corpectomy, and 34% (n=68) posterior or antero-posterior 360° fusion+corpectomy. Surgical complications occurred in 1% (kyphoplasty) and 10% (instrumented surgery). In 26% surgery was performed at a median 3 years following the diagnosis of the vertebral lesion. The leading indications for surgery were pain (73%) and instability according to SINS (68%). Patients treated surgically had significantly more potentially unstable or instable lesions according to SINS.

**Conclusions:** With this study, we report on a large cohort of 450 MM patients of which the majority (68%) received spine surgery. Vertebral pain and spinal instability according to SINS were the leading causes for surgery. With respect to spinal metastases of other entities, we see a comparatively low complication rate in patients treated with kyphoplasty or with reconstructive surgery, but prolonged time from initial diagnosis of symptomatic spinal lesion to surgical management. Further prospective cohort studies are needed to generate robust data on optimal timing and technique of surgical intervention in MM patients.

## V 55

**Dural closure with non-penetrating titanium clips in spine surgery**\*J. Hofereiter<sup>1</sup>, M. Gagliardi<sup>1</sup>, S. Akahori<sup>1</sup>, J. Wilson<sup>1</sup>, C. Witiw<sup>1</sup>, H. Ginsberg<sup>1</sup><sup>1</sup>Toronto Western Hospital, University Health Network, Neurosurgery, Toronto, Kanada

**Introduction:** Postoperative cerebral spinal fluid (CSF) leakage constitutes a troublesome complication in spine surgery and could potentially lead to severe consequences. Intradural lesions are particularly susceptible to this occurrence, hence an efficient watertight dural closure is required. The standard technique comprises suturing the dura mater. More recently, dural closure using non-penetrating titanium clips (hemoclips) has been proposed as an alternative technique. Accordingly, we aimed to assess the effectiveness of these techniques in preventing postoperative CSF leaks in patients undergoing spinal intradural surgery.

**Methods:** We analyzed a cohort of adult patients diagnosed with intradural spinal lesions (tumour, dAVF, etc.) treated with surgery between 2014 and 2021. Dural closure was performed either with sutures or hemoclips. The primary outcome measures were the occurrence of pseudomeningocele, clinical evidence of CSF leak, and rate of revision surgery due to CSF leak. In addition, we assessed for radiologic artifacts in follow-up imaging due to the closure material. Independent t test and Mann-Whitney test were used to determine differences in parametric and non-parametric continuous variables respectively. Fisher's exact test was used to determine differences in categorical variables between the two cohorts. Statistical significance was set at  $P < 0.05$ .

**Results:** A total of 114 patients diagnosed with intradural spinal lesions treated with surgery between 2014 and 2021 were analyzed. After thorough assessment for inclusion and exclusion criteria, 91 participants (suture group n=57, hemoclip group n=34) were finally included in the analysis. Age, sex, follow-up time and interval between the surgery and the first outpatient follow-up MRI assessing for pseudomeningocele were similar in both groups. In relation to the primary outcome measures, there was no significant difference in the rate of pseudomeningocele (n=6 suture group vs. n=4 hemoclip group), and there were no patients that had clinical evidence of CSF leak or required revision surgery due to CSF leak. In addition, no significant radiologic artifacts were noticed on postoperative MRI imaging.

**Conclusion:** The occurrence of radiological or clinical CSF leakage after an intradural spine procedure was similar in patients who underwent dural closure with sutures or hemoclips. Furthermore, hemoclips did not interfere with the evaluation of postoperative imaging. This study suggests that hemoclips may be an equally effective but more efficient strategy for dural closure.

#### V 56

##### Pilot study on the learning effectiveness of anatomical knowledge and practical spinal surgery skills using a new VR-based training platform

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**Introduction:** Due to the increasing complexity of spinal surgery, the demand for new, optimized teaching and training methods is increasing. In addition, technological progress leads to increasing and successful usage of virtual reality (VR) simulations for training and further education across different sectors. Therefore, the aim of the prospective, randomized pilot study (ethics committee vote no. 15/2/22) is to examine whether the knowledge and the necessary skills to safely carry out a frequent, complex spinal surgical technique (pedicle screw placement) can be learned virtually using a new VR based 3D training platform.

**Material and methods:** Twenty-eight study participants received conventional preliminary instruction (group lecture hall (HS), n=14) or a VR lecture with the same content using 3D models of clinically relevant anatomy. In addition, the surgical technique was simulated and practiced using a VR training platform (group VR, n=14). The learning effectiveness of both teaching methods was evaluated using a multiple-choice (MC) test (30 min, 15 questions) and a practical exercise (skills test on a bone model). Finally, specially developed questionnaires (self-assessments) were used for the subjective evaluation of both methods.

**Results:** Theory/MC test: 69% (range 53–87%, SD 0.10) of the questions were answered correctly in the HS group (n=11) whereas 66% (range 47–87%, SD 0.11) were answered correctly in the VR group (n=14) (p=0.692, t-test with independent samples).

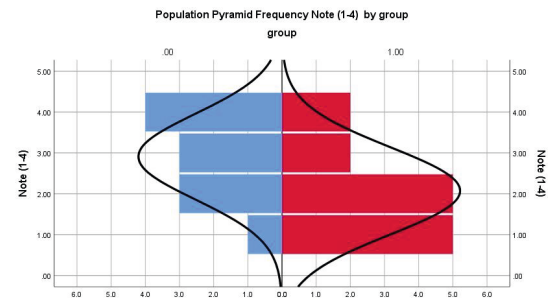
Practice/Skills Test: The overall assessment (n=25) in the practical learning objective check (pedicle screw placement on the bone model) resulted in 02.4 points (n=25; range 1–4). Participants in the VR group performed better with grade 02 (grade range 1–4) (HS group grade 02) (Fig. 1).

Self-assessment: In the final subjective assessment, the virtual learning environment, 3D anatomy model, and the surgical simulation were rated comparably well (VR 03.9 (1–5 points) vs. 04 HS (0–5 points)).

**Discussion:** The pilot study showed that decentralized student teaching using a new VR-based 3D training platform yielded comparable results in teaching clinically relevant anatomy knowledge and knowledge transfer into practice to conventional preliminary teaching with a high acceptance of the new methods. The VR-based 3D training platform is continuously being further developed and is already a helpful addition and alternative to standard teaching and training methods.

**Fig. 1** Comparison of both groups (red=VR, blue=HS) in the overall assessment (Grades: 1= good performance / 4= poor performance) in the practical test (pedicle screw implantation on the bone model)

**Fig. 1**



#### V 57

##### Two years of COVID-19 and its impact on volume of surgical spine care in Germany – a German Spine Registry (DWG) analysis

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**Background:** The COVID-19 pandemic has largely affected spine care worldwide. At the beginning of the pandemic in Germany, surgical volume dropped markedly. Currently, it is unclear how surgical volume changed afterwards and especially during later pandemic waves. For this Registry study it was hypothesized that the COVID-19 pandemic in Germany is associated with a reduction of executed surgical spinal interventions, which was more prominent for specific spinal pathologies.

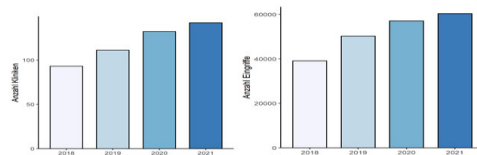
**Methods:** Surgical cases were selected from the German Spine Registry (DWG Register) during a 4-year period. Two groups were composed and compared. Patients enrolled prior to the start of the COVID-19 pandemic (before 01.01.2020) were included in group 'PRE-pandemic'. Patients admitted between 01.01.2020 and 31.12.2021 were selected for the group 'PANdemic'. We compared surgical volume over time and between groups. Subanalysis of specific pandemic waves and the impact on surgery for specific spinal pathologies was studied as well. In order to optimize comparability, institutions that provided information during the entire study period were studied separately as well (adjusted analysis)

**Results:** A total of 206841 patients have been identified. The pre-pandemic group included 89405 cases, whereas the PANdemic group had 117436 cases. A total of 142 institutions managed to include patients for this study (Fig.1a/b). As anticipated, monthly surgical volume did not differ between 2018 and 2019. However, an altered annual distribution pattern was seen in the pandemic years 2020 and 2021 (Fig.2a/b). The additional adjusted analysis included 96 identical clinics. In parallel to pandemic waves, a drop in executed interventions was seen in the PANdemic group. Following the 1st pandemic wave, restoration of normal surgical volume took 3 months, whereas after later waves, normalization of surgical spine care occurred faster. Furthermore, following waves in 2021, a compensatory upsurge of surgical volume was seen. The most prominent reduction of surgical volume was seen in patients with degenerative diseases. In addition, a striking drop of performed interventions for critical categories such as infection and tumours occurred as well.

**Conclusion:** The current study demonstrates that the COVID-19 pandemic is associated with decreased surgical load. However,

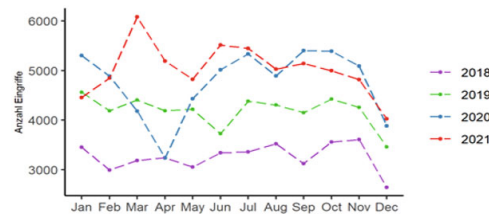
restoration after pandemic waves occurs faster and more profound. Not only elective surgery rates dropped but also interventions for critical indications. During periods of peak COVID-19 incidences not only a decrease in performed elective surgeries was seen, but also the number of interventions for critical conditions dropped markedly. More protocols are required to optimize restoration of surgical volume after pandemic waves for different spine pathologies.

**Fig. 1**

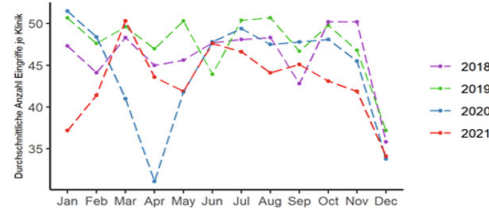


Figur 1a: Anzahl der Kliniken per Jahr  
Figur 1b: Absolute Anzahl der Eingriffe per Jahr

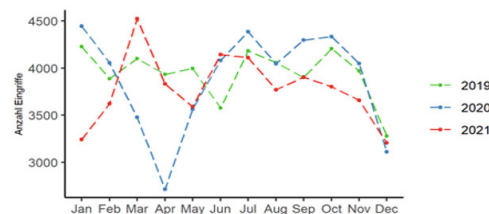
**Fig. 2**



Figur 2a: Monatsanalyse Absolute Anzahl der Eingriffe



Figur 2b: Monatsanalyse Normierte Anzahl Mittelwert der Eingriffe



Figur 2c: Monatsanalyse der identischen Kliniken 2019, 2020 und 2021

## V 58

### A comparison of thoracic single-curve vs. double-curve adolescent idiopathic scoliosis in clinical prospective registry study

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**Introduction:** The clinical and radiological data of adolescent idiopathic scoliosis (AIS) with structurally thoracic single curves often differ compared to double curves. However, is this reflected in patient satisfaction?

**Material/Method:** AIS data from a scoliosis center were prospectively collected and retrospectively analyzed as part of a

multicenter study by the DWG. Operation May 2019 to March 2021, follow-up (FU) after 12 months. All patients underwent standing X-rays of whole spine in 2 planes before surgery and at FU, as well as preop bending images. Clinical data and patient-related outcome measurements (SRS-30 questionnaire) were collected preop and at FU. Comparison of structural thoracic single curve AIS (Lenke type 1, SC) vs. double curve AIS (Lenke types 3 and 6, DC). Data as mean±SD. Differences in group-specific parameters (SC vs. DC) were analyzed by student's t test (significance  $\alpha=0.05$ ).

**Results:** A total of 44 patients (f 91%) were included. 100% completed radiographs as well as SRS-30 questionnaires. Mean age was  $14.8\pm 1.4$  years, mean FU  $17.2\pm 6.3$  months. 68% of AIS were classified as SC (1A=20, 1B=5, 1C=5) and 32% DC (3C=5, 6C=9). Mean fusion length was  $9.4\pm 2.2$  segments (SC= $9.2\pm 1.9$ , DC= $9.7\pm 2.5$ ,  $p=0.5$ ), upper and lower (LIV) instrumented vertebrae differed significantly (SC: average T4 and L1, DC: T6 and L4,  $p<0.05$ ), mean surgery time and blood loss did not significantly differ ( $207\pm 66$  vs.  $226\pm 64$ min,  $p=0.4$ ;  $453\pm 337$  vs.  $602\pm 381$ ml,  $p=0.2$ ). Mean thoracic (TC) and lumbar curve (LC) were  $62.1\pm 12.6^\circ$  vs.  $56\pm 14.7^\circ$  ( $p=0.2$ ) and  $37.8\pm 10^\circ$  vs.  $62.9\pm 8.9^\circ$  ( $p<0.05$ ), respectively. The mean correction (FU) was significantly different for TC:  $71\pm 15\%$  vs.  $59\pm 16\%$  ( $p<0.05$ ), not significant for LC:  $64\pm 23\%$  vs.  $67\pm 11\%$  ( $p=0.5$ ). Significantly different was correction of lumbar hump:  $-3.8\pm 4.9^\circ$  vs.  $-14.6\pm 11.7^\circ$  ( $p<0.05$ ), non-significant corrections of high thoracic and thoracic rib hump ( $p=0.3$ ;  $p=0.2$ ). LIV-tilt and C7 plumb line deviation were significantly lower postoperatively in SC:  $4.8\pm 3.4^\circ$  vs.  $8\pm 3.6^\circ$  and  $10.6\pm 9.9^\circ$  vs.  $21\pm 16.4^\circ$  ( $p<0.05$ ). No significant differences for thoracic kyphosis ( $p=0.7$ ), lumbar lordosis ( $p=0.5$ ), clavicle angle ( $p=0.5$ ) and spinopelvic parameters ( $p>0.4$ ).

Average SRS-30 total score was  $3.6\pm 0.5$  vs.  $3.5\pm 0.4$  before surgery ( $p=0.4$ ), significantly better for SC  $4.4\pm 0.3$  vs.  $4.1\pm 0.3$  at FU ( $p<0.05$ ). Self-image improved in 73% (SC) vs. 43% (DC) of patients. Only subcategories "activity and function" and "self-image" showed significantly better mean scores for SC at FU ( $p<0.05$ ).

**Discussion:** In conclusion, the results of this study show good surgical correction. Single-curve AIS have subjectively better function and activity, self-image, and coronary balance one year after surgery compared to double-curve AIS.

## V 59

### Are conventional radiographs and MRI sufficient to classify osteoporotic vertebral body fractures according to the OF spine classification or do we need an additional CT Examination?

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**Purpose:** The purpose of this study was to compare the classification quality of osteoporotic vertebral body fracture (OVBF) using the OF spine classification between the combination of magnet resonance imaging (MRI) and computer tomography (CT) and MRI only.

**Methods:** Between 2017 and 2019 eighty-five consecutively and prospectively collected patients suffering of an acute thoracolumbar OVBF of a level II spine center were analyzed. All patients with OF type I and type V fractures were excluded. In all patients the level of mobilization, the pain level (visual analogue scale), degree of fracture sintering, neurological deficits, and risk factors in accordance with the OF score were documented. All fractures were initially classified by 5 orthopaedic surgeons after analyzing MRI and conventional radiographs. Next re-classification of all fractures was performed including the additional CT scan of these patients by the same 5 reviewers. Differences of the OF classification and the OF score between both

measurements were analyzed and the inter-rater reliability was calculated using Kappa values.

**Results:** A total of 61 patients were analyzed with a mean age 75.8 years (SD: 8.8 years, range 52 to 91 years) consisting of 44 women and 17 men. In accordance to the OF classification under consideration of both MRI and CT, there have been 8 type II fractures (13.1%), 40 type III fractures (65.6%), and 13 type IV fractures (21.3%). In 82.9% of the cases no difference of the OF types classified considering MRI versus MRI+CT could be seen. Differences of more than 2 OF types between the classifications were visible in less than 1% of all ratings. The inter-rater reliabilities of the OF classification based on CT+MRI and MRI alone are 0.63 and 0.49, respectively. In 97.5% of the cases there was no therapy-relevant difference of the treatment recommendation with respect of a surgical or nonoperative treatment recommendation based on the OF score.

**Conclusion:** The OF classification based on conventional radiographs and MRI has a high agreement compared to the classification based on an additional CT, particularly for the detection of fractures with higher instability such as OF 4 fractures. Additionally, there is only a minor rate of disagreement of 2.5% of the resulting treatment recommendation in accordance to the OF score between MRI and MRI+CT. Notwithstanding, the inter-rater RR was substantially using MRI+CT and moderate under consideration of MRI alone.

## V 60

### Optimization of the vertebral bone quality scores for the prediction of osteoporosis using magnetic resonance imaging, age- and sex-specific differences

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**Introduction:** Recent findings revealed a correlation between vertebral bone quality of T1-weighted (VBQ<sub>T1</sub>) magnetic resonance imaging (MRI) and volumetric bone mass density (vBMD) measured using quantitative computer tomography. Coherence among VBQ for other MRI sequences, such as T2 or short tau inversion recovery (STIR), has not been examined. Spinal marrow undergoes age- and sex-specific changes. Thus far, these parameters' influences on VBQ have not been studied. This study's aims were to confirm the correlation between VBQ<sub>T1</sub> and vBMD and to examine coherences of other VBQ scores with vBMD. Furthermore, the influences of age and sex on VBQ should be examined.

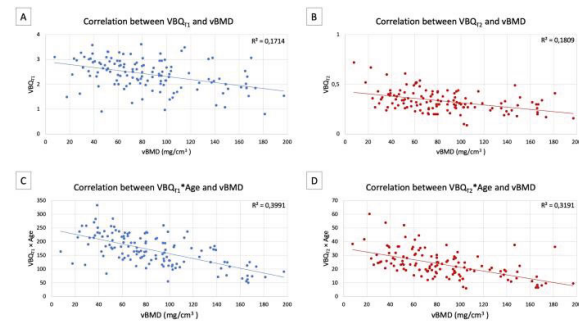
**Methods:** In a retrospective design (2019–2021), patients' VBQs were calculated with the signal intensities of the vertebral bodies L1–4 for T1-, T2-, and STIR-weighted MRI. The VBQ was normalized with the cerebrospinal fluid's signal intensity. The vBMD was determined with data from a calibrated scanner (SOMATOM Definition AS+) and processed with CliniQCT® (Mindways Software, Inc., USA). Groups were divided according to the vBMD into the following groups: (I) Osteoporosis/penia (<120 mg/m<sup>3</sup>) and (II) Healthy (≥120 mg/m<sup>3</sup>). An analysis of the correlation between various VBQs and vBMD as well as receiver operating characteristic (ROC) and binary regression analyses for the prediction of an osteoporosis/penia were performed.

**Results:** We included 136 patients (women: 57.4%) in the study. According to the vBMD, 108 patients (79.4%) had osteoporosis/penia. Women were affected significantly more often than men ( $p = 0.045$ ) and had significantly higher VBQ<sub>T1</sub> and VBQ<sub>T2</sub> than men (VBQ<sub>T1</sub>:  $p = 0.048$ ; VBQ<sub>T2</sub>:  $p = 0.013$ ). VBQ<sub>T1</sub> and VBQ<sub>T2</sub> values were significantly higher in patients with osteoporosis/penia than in healthy persons (VBQ<sub>T1</sub>:  $p < 0.001$ ; VBQ<sub>T2</sub>:  $p = 0.025$ ). VBQ<sub>T1</sub> and VBQ<sub>T2</sub> correlated significantly and negatively with vBMD ( $p < 0.001$ ). Multiplying VBQs by age raised the correlations' effect size considerably (Fig. 1). No significant differences or correlations were found for VBQ<sub>STIR</sub>. Sex-specific differences emerged in the product of VBQ and age: In women, VBQ<sub>T1</sub> × age showed the strongest effect size of the correlations, whereas

VBQ<sub>T2</sub> × age did so in men. A VBQ<sub>T1</sub> cutoff value of 2.101 predicted osteoporosis/penia with a sensitivity of 64.3% and a specificity of 78.3% (area under the curve [AUC]: 0.713). A binary logistic regressions analysis for the model  $P(\text{osteoporosis, penia} = 1) = 1 / 1 + e^{(-9.242 - 2.205 \times \text{VBQ}_{T1} + 0.909 \times \text{VBQ}_{T2} \times 0.078 \times \text{age} - 0.526 \times \text{sex})}$  had an AUC of 0.846.

**Discussion:** This study confirms the findings of a significant correlation between VBQ<sub>T1</sub> and vBMD. Additionally, a significant correlation between VBQ<sub>T2</sub> and vBMD emerged, and age demonstrated an important influence on VBQ. Furthermore, the results indicate a sex-specific use of VBQ<sub>T1</sub> and VBQ<sub>T2</sub> for better prognostic outcomes. An AUC above 0.8 for the mathematical model implies excellent prognostic qualities.

**Fig. 2**



## V 61

### Are there any differences in therapy of osteoporotic thoracolumbar vertebral fractures before and after the introduction of the OF-classification?

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**Introduction:** The OF classification (OFK), introduced in 2018, is used to support decisions regarding conservative vs. surgical treatment of osteoporotic thoracolumbar vertebral body fractures (OTF) (Schnake et al., 2018). Treatment failure can lead to serious complications.

**Material/Method:** Retrospective analysis of conservatively or surgically treated pat. due to OTF in a spine center. Subdivided by time of record: before (n=200) or after (n=200) introduction of the OFK in 2018. Pat. with treatment before 2018 were evaluated to determine whether the recommendation of OFK was followed at time of surgery. Outcome measures included type of procedure (conservative/surgical), segmental kyphosis, pain medication (WHO level I-III), antiosteoporotic medication, subsequent fractures during follow-up, any changes in therapy. Analysis with Chi<sup>2</sup> and Fisher's Exact – when possible, and t-tests for continuously distributed variables (significance  $\alpha = 0.05$ ).

**Results:** 400 pat. treated before and after 2018 were compared regarding numerous patient characteristics. Of all factors, the only significant difference was the distribution of OFK (OF 1-4: before 2018: 0%, 52%, 40.5%, 7.5%; after 2018: 1%; 60.8%, 29.2%, 9%;  $p < 0.05$ ). In total, 36.5% thoracic (median=Th11) and 64% lumbar fractures (median=L2).

Comparison of therapy before and after 2018 with significant difference: conservative: 44% before 2018, 58.5% after 2018 ( $p < 0.01$ ); surgical: 56% before 2018, 41.5% after 2018 ( $p < 0.01$ ). Significant differences for segmental kyphosis after treatment: 48% before 2018, 35% after 2018 ( $p < 0.05$ ); pain medication: before 2018: I=19.6%, II=6.0%, III=74.4%; after 2018: I=33.0%, II=7.5%, III=59.5% ( $p < 0.01$ ), antiosteoporotic medication: 35.5% before 2018, 51.0% after 2018 ( $p < 0.01$ ). No difference of concordance of therapy recommendation according to OFK: before 2018=62% and after 2018=61.5%. Pat. with OF 2 were significantly more likely to be treated with antiosteoporotic medication after 2018 (35.6% before, 54.6% after 2018;  $p < 0.01$ ).

In all pat. (before and after 2018) with treatment according to OFK, there were significantly fewer operative treatments (according to OFK: 43.3% operative, not according to OFK: 57.6% operative,  $p < 0.01$ ), as well as less kyphoplasties (32.8% vs. 55.6%,  $p < 0.01$ ) but more fusions (13.0% vs. 3.9%,  $p < 0.01$ ). The frequency of treatment change in case of failure during the follow-up did not differ significantly: in 4.1% (according to OFK) and 5.2% (not according to OFK) of the patients ( $p = 0.6$ ). Other outcome parameters also showed no significant differences depending on whether the OFK recommendation was followed or not.

**Discussion:** In summary, the results show that there are differences regarding OTF treatment before and after the introduction of OFK. Specifically, when rejecting the OFK therapy recommendation, more surgical treatments and kyphoplasties were performed. The difference did not affect treatment failures.

## V 62

### Survival and mortality rate after minimal-invasive hybrid stabilization (MIHS) in osteoporotic patients with unstable spinal fractures

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**Introduction:** Minimal invasive hybrid stabilization (MIHS) is a safe treatment alternative for dorso-ventral interventions in patients with unstable osteoporotic fractures (OF) of the spine. Minimal invasive interventions are associated with less post-operative pain and complication. MIHS allows for early mobilization and prompt hospital discharge. Long-term outcome including non-trauma mortality is relatively unclear. The current study aimed to determine post-operative survival and to identify predictive factors for mortality in osteoporotic patients.

**Methods:** Adult patients treated in a level one spine center by MIHS for unstable osteoporotic fractures of the lumbar and thoracic spine have been included. Trauma and patient characteristics as well as 2-year outcome have been analyzed. To identify factors that are associated with post-traumatic mortality we grouped and compared patients who SURVived the follow-up period and those patients who did not survive (MORTality-group).

**Result:** A total of 75 patients with a mean age of have been included of whom 72% were females. 49 patients were diagnosed with unstable OF 3 fractures, whereas 26 patients had OF 4 fractures. Mean duration of hospital stay was 13 (std: 7) days. 18.7 percent of patients had a complicated course. No in-hospital mortality occurred. During the 2-yr follow-up, a total of 19 fatalities occurred at a mean age of 82 (std: 6) years. Thereby, the 2-yr post-operative survival rate is 75%. In the MORT-group, the percentage of OF 4 fractures was lower than in the SURV-group (10.5 vs. 75.0%,  $p < 0.01$ ). Furthermore, overall operating time was longer in the MORT-group than in the SURV-group ( $p = 0.04$ ). Patients from the MORT-group had more frequently complicated in-hospital courses than those patients from the SURV-group (37.0% vs. 12.5%,  $p = 0.04$ ).

**Conclusions:** Minimal-invasive hybrid stabilization is a safe and feasible treatment option for unstable osteoporotic spine fractures. However, 2-year survival rates of 75% demonstrate that unstable spinal osteoporotic fractures are linked with significant impaired life expectancy. Patient specific characteristics do not affect post-discharge survival, however fracture type (OF 3, rather than OF 4), prolonged operating time and post-operative complications are associated with post-discharge mortality. To optimize treatment guidelines (and selection criteria for operative treatment modalities) for frail patients with unstable spinal fractures, more prospective multicenter studies are indicated

## V 63

### Increased spinal cord motion is associated to pathologic sensory and electrophysiological readouts in degenerative cervical myelopathy

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**Background:** The pathophysiology of degenerative cervical myelopathy (DCM) is inadequately understood and static compression of the cord often lacks to explain a patient's status [1–3]. Recently, increased and ongoing cardiac-related spinal cord motion emerged as a potential contributing factor [4–8], exerting dynamic mechanical stress onto the spinal cord. We aimed to investigate the impact of increased spinal cord motion on clinical findings compared to static cord compression.

**Methods:** Ninety-six DCM patients underwent a clinical assessment (mJOA score, cervical segmental light touch and pinprick perception, cervical segmental motor score) and electrophysiology (contact heat evoked potentials for spinothalamic tract; dermatomal somatosensory evoked potentials for dorsal column). Spinal cord motion was quantified with phase-contrast MRI, static compression was evaluated in axial T2 weighted MRI. The diagnostic value of increased segmental spinal cord motion (i.e., displacement) in comparison to the extent of static cord compression (i.e., adapted spinal canal occupation ratio – aSCOR) to identify pathologic clinical (i.e., sensorimotor assessments) and electrophysiological readouts was evaluated by means of receiver operating characteristic analysis.

**Results:** In 96 patients (female: 35.4 %; age:  $55.7 \pm 13.3$  years) mJOA score was  $15.8 \pm 2.0$  points. Increased spinal cord motion (i.e., displacement) was superior compared to measures of static compression (i.e., aSCOR) to identify patients with pathologic readouts. This was true for segmental sensory readouts (e.g., segment C4: displacement: light touch – AUC 0.668; pin prick – AUC 0.685; aSCOR: light touch – AUC 0.518; pin prick – AUC 0.497) and electrophysiologic measures of spinothalamic tract damage (i.e., segment C5: pathologic contact heat evoked potentials – displacement: AUC 0.778; aSCOR: AUC 0.585).

**Discussion:** Increased spinal cord motion was superior associated to pathologic clinical and electrophysiological findings in DCM patients compared to measures of static compression. Therefore, spinal cord motion readouts provide complimentary information on dynamic spinal cord distress and may be of value for the diagnostic workup. As true for anatomical measures of cord compression the critical threshold values of spinal cord motion, identifying patients with mild DCM at risk for disease progression have to be validated in a prospective analysis.

## V 64

### Spinal motion and low back pain – prospective analysis of the association between lumbar movement and the presence of chronic pain

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**Introduction:** Despite the rising prevalence of chronic low back pain (LBP), due to a lack of understanding of the underlying mechanisms of pain development, therapeutic management of LBP remains challenging. While in the past, adaptations of spinal motion in the presence of LBP have been increasingly studied, little is known about the quantitative analysis of lumbar movements. Thus, in our study, we for the first time investigated movements of the lumbar spine of both asymptomatic participants and LBP patients in their daily lives.

**Material/Methods:** We prospectively included both asymptomatic participants and patients who had been suffering from LBP for at least twelve weeks. A body-mass-index (BMI) of  $>26 \text{ kg/m}^2$  was an

exclusion criterion. All asymptomatic participants as well as LBP patients were measured for 24 hours during their daily lives using the Epionics SPINE System with the standing position as a reference. Lumbar movements of over 5° were recorded independently from the movement's starting position and were grouped into movements of 5-10°, 10-15°, and >15°. For statistical analysis, the Student's t-test, analysis of variance (ANOVA) with Bonferroni post-hoc test, and the Spearman correlation coefficient were used.

**Results:** A total of 208 asymptomatic participants and 106 LBP patients were included. While the groups did not differ significantly in the distribution of sexes or in their BMIs, the group of LBP patients was significantly older (50.9±13.6 vs. 40.3±14.0 years, p<0.001). We found significantly fewer small, medium, and large movements in the sagittal plane (total movement count 15,564±8,078 vs. 20,521±7,160, p<0.001; Fig. 1) in the group of LBP patients. In the axial plane, LBP patients were shown to perform significantly fewer small movements (total movement count 7,317±5,881 vs. 11,106±5,134, p<0.001; Fig. 2). There was a weak but significant correlation between age and the number of sagittal (r=-0.179, p=0.010) as well as axial (r=-0.172, p=0.013) movements shown for the group of asymptomatic participants, while in LBP patients this correlation was only found for sagittal movements (r=-0.290, p=0.003).

**Discussion:** Our results show that in addition to a significantly reduced total amount of lumbar movements in LBP patients compared to asymptomatic participants, there are significant differences between men and women especially regarding large sagittal movements. We also found a reduction in lumbar movement with increasing age, the correlation of which, however, was only weak. While it remains unclear whether the shown changes in spinal motion are cause or effect of pain development, the association between movement adaptations and chronic LBP needs to be considered in the optimization of motion-based conservative treatment strategies and therefore needs to be further investigated.

Fig. 1

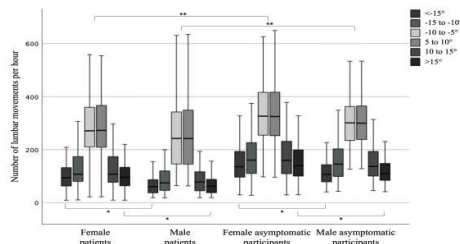


Fig. 1. The number of lumbar movements in the sagittal plane performed in each group. Significant differences between two movement groups are marked with \*, significant differences between all movement groups with \*\*.

Fig. 2

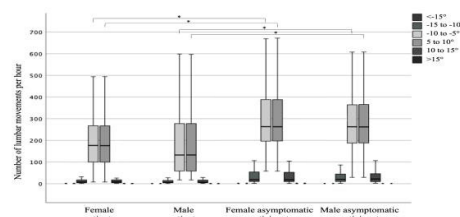


Fig. 2. The number of lumbar axial rotation movements per hour for each group. Significant differences are marked with \*.

V 65

**Osteosarcopenia in the spine – association between paraspinal muscle impairment and advanced glycation endproducts in lumbar fusion patients**

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**Background:** Impaired bone integrity and muscle function are described as osteosarcopenia. Bone integrity is composed of bone quantity (bone mineral density) and quality (microarchitecture and collagen). The accumulation of advanced glycation end products (AGEs) by non-enzymatic collagen cross-linking stiffens collagen fibers and increases bone fragility. The relationship between lumbar muscle quality and bone collagen properties has not yet been assessed. We hypothesized that an accumulation of AGEs, a marker of impaired bone quality, is associated with impaired muscle quality (increased intramuscular fat).

**Methods:** A cross-sectional analysis using prospectively collected data of patients undergoing posterior lumbar spinal fusion for degenerative conditions was conducted. Preoperative MRI measurements at level L4 included m. *psaos* and combined m. *multifidus* and *erector spinae* (posterior paraspinal musculature, PPM). Manual muscle segmentation on axial T2-weighted images (cross-sectional-area, CSA) using ITK-SNAP and subsequent calculation of an automated pixel intensity threshold method (Matlab version R2019a) to differentiate muscle (functional-cross-sectional-area, fCSA) and intramuscular fat (FAT). Intraoperative bone biopsies from the posterior superior iliac spine were obtained and evaluated with multiphoton fluorescence microscopy for fluorescent AGE crosslink density (fAGEs). Quantitative computed tomography (QCT) measurements were performed at the lumbar spine. Correlations between fAGEs (trabecular and cortical) and paraspinal muscle morphology parameters (CSA, FAT, fCSA) were assessed with Spearman's  $\rho$ . Multivariable linear regression models with adjustments for age, sex, BMI, race and diabetes mellitus were used to investigate associations between fAGEs and paraspinal musculature.

**Results:** 107 prospectively enrolled patients (50.5% female, age 60.7years, BMI 28.9kg/m<sup>2</sup>) were analyzed. 41.1% and 15.0% of the patients demonstrated osteopenia and osteoporosis in the lumbar spine respectively. Univariate analysis demonstrated a significant association between cortical fAGEs and CSA in the m. *psaos* ( $\rho=0.220, p=0.039$ ), but not in the PPM. Trabecular fAGEs revealed no significant associations to PPM or *psaos* musculature. In the multivariable analysis higher cortical fAGEs were associated with increased FAT ( $\beta=1.556; p=0.002$ ) and CSA ( $\beta=1.305; p=0.005$ ) in the PPM after adjusting for covariates.

**Conclusion:** This study demonstrated that an accumulation of the non-enzymatic collagen cross-linking products fAGEs in cortical bone is associated with increased intramuscular fat in the lumbar paraspinal musculature. Our findings elucidate the relationship between bone collagen modifications and paraspinal muscle composition. This might reflect crucial interactions contributing to osteosarcopenia in the spine beyond bone mineral density.

Fig. 1

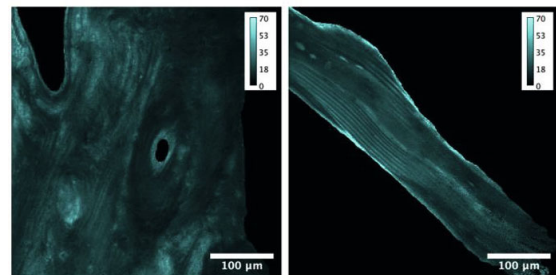
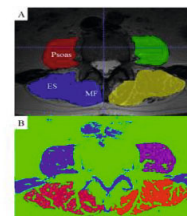


Fig. 2



## V 66

**The influence of therapy expectation on pain and disability in interdisciplinary multimodal pain therapy**\*C. G. Levenig<sup>1</sup>, M. I. Hasenbring<sup>1</sup>, S. Elsenbruch<sup>1</sup>,  
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**Background:** Chronic low back pain (CLBP) causes both a high individual and socioeconomic burden worldwide. In the treatment of CLBP, the interdisciplinary multimodal pain therapy (IMPT) is more effective than usual care regarding the reduction of pain intensity and pain-related disability. The importance of individual attitudes and expectations towards the therapy and its outcomes is essentially high. However, there is a lack of studies examining therapy expectations (TE). In the course of this prospective study, we examined the relation between TE, pain intensity and disability in patients suffering from CLBP.

**Methods:** 227 patients (67.6% female, 59.96 ± 13.16 years) with CLBP filled in the Therapy Expectation Questionnaire at the beginning (T1) of their inpatient IMPT therapy. Pain intensity was measured at T1, at the end of therapy (T2) and after 3 months (T3), disability was measured at T1 and T3. To investigate the influence of IMPT on pain outcomes, we conducted an analysis of variance with repeated measures (rmANOVA) with the factor *time* (T1 vs. T2 vs. T3) for pain intensity and a t-test for dependent samples (T1 vs. T3) for disability. The predictive value of TE for changes within pain outcomes was investigated by separate multiple regression analyses.

**Results:** The rmANOVA showed a significant main effect of *time* ( $F(1.88, 243.71) = 64.65, p < .001, \text{partial } \eta^2 = .33$ ). Post-hoc tests revealed significantly lower pain intensities at T2 ( $p < .001, \text{MDiff} = 11.65, 95\%-\text{CI} [8.97, 14.33]$ ) and T3 ( $p < .001, \text{MDiff} = 12.29, 95\%-\text{CI} [8.98, 15.59]$ ) compared with T1. In concerns of pain-related disability, a significant reduction between T1 and T3 was shown ( $t(106) = 6.46, p < .001, d = .63$ ). After adjustment for age and sex, TE emerged as a significant predictor for reductions in both pain intensity ( $R^2 = .08, \beta = -1.86, p < .05$ ) and disability ( $R^2 = .09, \beta = -5.42, p < .01$ ). Thus, more positive TE and a higher age of the patient predicted decreased pain intensity. More positive TE also predicted decreased disability.

**Discussion:** Our results suggest the relevance of positive TE concerning pain outcomes of IMPT. This confirms results of research involving placebos and is significant for clinical contexts with regard to that optimizing the TE in psychosocial contexts established therapy concepts could be improved. Future research has to investigate, if negative TE have an effect (Nocebo) and if compliance and adherence play a role.

**Keywords:** therapy expectation, low back pain

## V 67

**Genetic and epigenetic profiling identifies two distinct classes of spinal meningiomas**\*F. Ricklefs<sup>1</sup>, K. Fita<sup>1</sup>, M. Mohme<sup>1</sup>, C. Mawrin<sup>2</sup>, F. Sahn<sup>3</sup>,  
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**Background:** Spinal meningiomas account for 1.2-12% of all meningiomas and 25-45% of all spinal tumours. About 20% of intracranial meningiomas and 4.6% of spinal meningiomas recur and require additional treatment. The classification of intracranial meningiomas has evolved considerably in recent years and uses genetic as well as epigenetic parameters in order to more precisely predict the patients' prognosis and to lay the ground for therapeutic regimens that are adapted to the aggressiveness of a patient's tumor. Spinal meningiomas are missing in many of the large cohorts that were gathered for molecular profiling of meningiomas

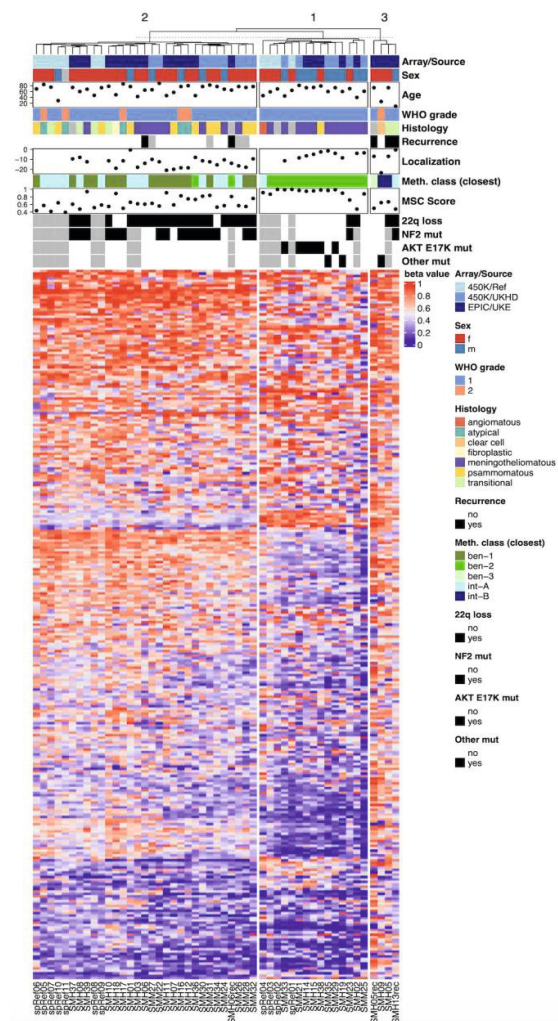
and were neither ever thoroughly analyzed separately, so that their classification still relies solely on histopathological findings.

**Methods:** We performed methylation profiles of 50 spinal meningiomas as well as targeted gene panel next generation sequencing (NGS). 570 intracranial meningiomas were used as a reference cohort. Copy number variations (CNV) were inferred from the methylation data. Principal component (PCA) and t-SNE analysis were conducted. Clinical and histopathological parameters (location, size, recurrence, WHO°, pathological subtype) were correlated with methylation signatures, that were additionally classified using the DKFZ brain tumour classifier.

**Results:** PCA and t-SNE analysis revealed shows that most spinal meningiomas separated from cranial meningiomas (46/50) and build 2 distinct cluster. Most of the cases in cluster 1 (n=15) significantly matched to the methylation class "benign-2", while cases in cluster 2 (n=31) were more heterogeneous with only 13/50 samples having a significant match at all (MSC score >0.9). Spinal meningiomas in cluster 1 were located in the upper spine, were significantly more common in male patients ( $p < 0.001$ ), were mostly meningotheliomatous, and had an AKT1 E17K mutation in 6/10 cases. *NF2* mutations were found in 16/21 spinal meningiomas of the second cluster. In line with this observation, a loss of chromosome 22q was observed in 28/31 cluster 2 cases, but only in 2/15 cluster 1 cases ( $p < 0.0001$ )

**Conclusion:** Our data suggest that genetic and genome-wide DNA methylation profiles identifies two distinct meningioma subclasses, that may not be achieved by standard histopathology and could lead to a better prognosis of spinal meningioma patients.

Fig. 1





## V 68

**Towards automated planning of lumbar pedicle screws in navigation and robotics – comparison of a commercial atlas-based to a self-derived deep learning-based approach**\*M. Scherer<sup>1</sup>, L. Kausch<sup>2</sup>, A. Bajwa<sup>1</sup>, B. Ishak<sup>1</sup>, K. Kiening<sup>1</sup>, J. O. Neumann<sup>1</sup>, K. Maier-Hein<sup>2</sup>, A. W. Unterberg<sup>1</sup><sup>1</sup>Universitätsklinikum Heidelberg, Klinik für Neurochirurgie, Heidelberg, Deutschland<sup>2</sup>Deutsches Krebsforschungszentrum (DKFZ) Heidelberg, Medical Image Computing, Heidelberg, Deutschland

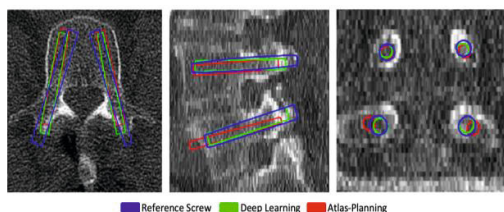
**Introduction:** Advancements of navigated or robotic procedures in spinal surgery require dedicated screw planning prior to implantation. We recently described a deep learning-based (DL) approach to automated planning of pedicle screws, which matched accuracy of manual screw planning by expert spine surgeons in a fraction of time expense. The aim of this study was to compare accuracy of a self-derived DL approach to a commercially available atlas-based (AB) system for pedicle screw planning.

**Methods:** From a consecutive registry of CT-navigated instrumentations, 50 cases covering 266 screws placed in L1-L5 were randomly selected. Using the Brainlab® iPlan Spine App, reference screws were manually planned by two independent raters defining the ground truth (GT) for screw positions and dimensions. Additionally, screws were planned using a self-derived DL approach and the atlas-based Brainlab® iPlan Spine automatic planning tool. Using Python, both automatic planning results were compared to the GT in 3D space by the following metrics: minimal absolute distances (MAD) of respective head and tip points (in mm) and angular deviation (in degree) (**Figure 1**). Results were evaluated in comparison to interrater variability of manual screw planning and qualitative evaluation by the Gertzbein-Robbins (GR) Classification

**Results:** Automatic planning was successful in all 266 screws with the DL approach and in 210/266 (79%) with the AB approach. Compared to the GT, MADs in DL planning for angular deviation, head and tip points were  $5.1 \pm 2.9^\circ$ ,  $4.5 \pm 2.9$ mm and  $3.6 \pm 2.5$ mm, respectively. For AB planning, corresponding MADs were  $7.2 \pm 5.9^\circ$ ,  $8.9 \pm 4.7$ mm and  $9.8 \pm 9.9$ mm, respectively. Interrater variance for manual screw planning was  $5.2 \pm 3.2^\circ$ ,  $4.4 \pm 1.6$ mm and  $3.7 \pm 1.7$ mm, respectively. Differences to GT for DL planning were statistically comparable to interrater variance of manual screw planning ( $p=0.62$ ). AB planning exhibited significantly greater differences to either DL ( $p<0.001$ ) and interrater variability ( $p<0.001$ ), respectively. Qualitatively, all DL screws were clinically acceptable (GR-grade A 255, 96%; B 11, 4%) while AB results were heterogeneous (GR-grade A 159, 60%; B 24, 9%; C 10, 4% D 16, 6% E 5, 2%; **no result** 52, 19%). DL produced significantly more clinically acceptable screws compared to AB ( $p$

**Conclusion:** DL based screw planning exhibited convincing accuracy compared to the GT in quantitative and qualitative evaluation in all targeted screws. DL results were statistically indifferent to the observed interrater variance of manual screw planning. In contrast, AB screw planning was feasible in a majority of targeted cases but showed inferior results requiring further post-processing prior to screw implantation. DL based applications appear as a promising approach to automated screw planning given the frequent anatomic variations of the spine severely limiting the accuracy of AB systems.

Fig. 1



**Figure 1:** Illustration of screw evaluation. Deviations of screw head and tip points and angular deviation were automatically calculated in Python for deep-learning and atlas-based screws vs. corresponding reference screws, respectively.

## V 69

**Functional recovery in relation to the posttraumatic restitution of the Blood-Spinal-Cord-Barrier after experimental Spinal Cord Injury in the mouse**L. Meyer<sup>1</sup>, L. Waldmann<sup>1</sup>, N. Taheri<sup>1</sup>, L. Roofls<sup>1</sup>, K. Kersting<sup>1</sup>, M. Nieminen-Kelhä<sup>1</sup>, I. Kremenetskaia<sup>1</sup>, A. Ghorri<sup>1</sup>, A. Rex<sup>2</sup>, M. G. Fehlings<sup>3</sup>, P. Vajkoczy<sup>1</sup>, \*V. Hubertus<sup>1,4</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Klinik für Neurochirurgie, Berlin, Deutschland<sup>2</sup>Charité – Universitätsmedizin Berlin, Experimentelle Neurologie, Berlin, Deutschland<sup>3</sup>Toronto Western Hospital, University Health Network, Neurosurgery, Toronto, Kanada<sup>4</sup>Charité – Universitätsmedizin Berlin, Berlin Institute of Health, Berlin, Deutschland

**Objective:** Spinal Cord Injury (SCI) is a devastating condition that presents a major socioeconomic burden for healthcare systems. The posttraumatic disruption of the Blood-Spinal-Cord-Barrier (BSCB) is a leading pathophysiology in SCI and its restitution plays a crucial role in structural spinal cord regeneration. A deeper understanding of the pathophysiology and its timeframe will enhance the search for restorative therapies facilitating functional regeneration. With this study we characterize the posttraumatic BSCB disruption and restitution in relation to functional recovery in a mouse model up to 28 days post SCI.

**Methods:** Adult C57BL/6J mice (m/f, n=55) underwent mid-thoracic (Th6/7) clip-compression SCI using a modified aneurysm clip (5g, 60s) or sham injury (two-level-laminectomy). Perioperative antibiotic therapy with amoxicillin and postoperative pain medication with buprenorphine was applied. Longitudinal neurobehavioral analysis was performed (n=23) using Catwalk® automated gait analysis and Basso Mouse Scale with Tally subscore at days 1, 3, 7, 14 and 28 post SCI. Additionally, *in vivo* imaging with 7T MRI was performed for tissue morphology analysis. Individual specimens were sacrificed at each time point for qualitative histological analysis (Luxol-Fast-Blue + H&E, CD31+Evans-Blue, n=5). BSCB disruption was quantified by measuring Evans-Blue (EVB)-extravasation via fluorescence microplate reader (Tecan, n=50). Animal experimental permission was granted (G031417).

**Results:** As the posttraumatic disruption of the BSCB is most severe up to day 7 post SCI, histological analysis up to this point showed vast structural damage and edema to the spinal cord with considerable EVB-leakage, supported by MRI findings, with an increasing restitution in the chronic phase (14d, 28d). Quantitative assessment of EVB-extravasation displayed a significant disruption of the BSCB up to 14 days post SCI (14d:  $p=0.001$ ), with restitution after 28 days ( $p=0.096$ ). Neurological recovery started between days 7 and 14 post SCI, with most specimens having regained hindlimb function by day 28 ( $p=0.552$ ).

**Conclusions:** Functional recovery following SCI is associated with the restitution of the BSCB, which remains significantly disrupted up to 14d post SCI, revealing a potential time frame for therapy application. Further detailed examinations of the regenerative capacities and the molecular players involved in BSCB regeneration are necessary for the development of restorative therapies targeting the neurovascular unit.

## V 70

**Extracellular vesicles versus entire MSC secretome: Do they provoke different effects on pro-inflammatory annulus fibrosus cell cultures?**\*G. Q. Teixeira<sup>1</sup>, J. Kräutler<sup>1</sup>, J. Riegger<sup>2</sup>, A. Ignatius<sup>1</sup>, C. Neidlinger-Wilke<sup>1</sup><sup>1</sup>Universitätsklinikum Ulm, Institut für Unfallchirurgische Forschung und Biomechanik, Ulm, Deutschland<sup>2</sup>Universitätsklinikum Ulm, Institut für Unfallchirurgische Forschung und Biomechanik, Ulm, Deutschland

**Objective:** Extracellular vesicles (EV) secreted by mesenchymal stem cells (MSC) have been shown to reduce cell apoptosis and inflammation in intervertebral disc (IVD) degeneration models and to promote extracellular matrix synthesis and proliferation of IVD

cells<sup>1</sup>. Additionally, priming of MSC with interleukin (IL)-1 $\beta$  has been shown to improve the pro-anabolic effect of the entire MSC secretome on IVD<sup>2</sup>. Therefore, we investigated the impact of EV *versus* entire secretome from IL-1 $\beta$ -primed and non-primed MSC on annulus fibrosus (AF) cells in a pro-inflammatory environment.

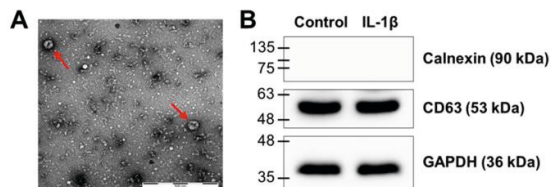
**Material/Methods:** (1) Human MSC were cultured with or without 1 ng/mL IL-1 $\beta$  for 48h (n=3), after which EV were purified from the entire secretome by differential (ultra-)centrifugation. EV morphology, particle diameter and size distribution/polydispersity were assessed by transmission electron microscopy (TEM) and dynamic light scattering. CD63 and calnexin expression by EV was analysed by western-blot. (2) Human AF cells were cultured with IL-1 $\beta$  for 48h (n=8). Subgroups of IL-1 $\beta$ -stimulated AF cells were treated with either entire secretome (Sec) or EV from non-primed (Control Sec or Control EV) or IL-1 $\beta$ -primed MSC (IL-1 $\beta$  Sec or IL-1 $\beta$  EV) (n=4-8). Unstimulated AF cells were used as control. Subsequently, cell metabolic activity, gene expression of *BAX*, *IL6*, *IL8*, matrix metalloproteinase *MMP1*, MMP inhibitor *TIMP1* and collagen type I (*COL1A1*) were evaluated. Statistics: one-way ANOVA (p<0.05). **Results:** Both Control and IL-1 $\beta$  EV displayed typical size distribution (diameter of 105 $\pm$ 53 nm, PdI of 0.30; Fig. 1A), expressed the positive EV marker CD63 and did not express calnexin, a negative EV marker (Fig.1B). IL-1 $\beta$  stimulation of AF cells increased cell proliferation and metabolic activity, as well as expression of *IL6*, *IL8*, *MMP1* and *TIMP1* *versus* control, while downregulating *BAX* and *COL2A1* (p<0.05, Fig. 2). All treatment groups decreased *BAX*, *IL6* and *IL8* expression by AF cells compared to IL-1 $\beta$  stimulation alone; but the secretome from primed and non-primed MSC also downregulated *TIMP1* and *COL1A1* (p<0.05). AF cell treatment with IL-1 $\beta$  EV upregulated *TIMP1* (p<0.0001) and did not further decrease *COL1A1*.

**Conclusion:** Overall, the results demonstrate a stronger anti-inflammatory effect of entire MSC secretome on human AF cells, but also on *COL1A1* downregulation, with no priming differences. Interestingly, the EV from primed MSC (IL-1 $\beta$  EV) may have a stronger effect on AF matrix metabolism than on the inflammatory response. A therapeutic advantage would be that the EV are more standardisable in terms of their content than the entire secretome. Investigations of the proteomic content of the EV and secretome to identify potential effector molecules/subsequent pathways is ongoing.

**Acknowledgment:** Deutsche Wirbelsäulenstiftung.

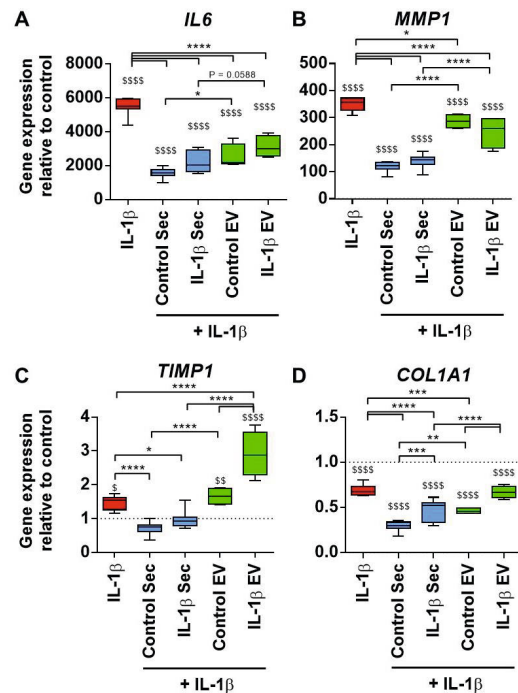
**References:** 1. Piazza et al, 2020. 2. Neidlinger-Wilke et al, 2021.

**Fig. 1**



**Fig. 1** A) TEM image of purified EV (arrows). B) CD63 and calnexin detection by western blot in EV secreted by non-primed (control) and IL-1 $\beta$ -primed MSC.

**Fig. 2**



**Fig. 2** Relative mRNA expression of A) inflammation marker *IL6*, B) matrix degrading enzyme *MMP1*, C) its inhibitor *TIMP1* and D) *COL1A1* for IL-1 $\beta$  stimulated AF cells and subsequently treated with secretome (Sec) or EV from control or IL-1 $\beta$ -primed MSC. Results were normalized to *GAPDH* and control cells. n=4-8; §, comparison to control; \*, comparison between treated groups and IL-1 $\beta$  stimulation alone.

## V 71

### Systemic application of IL-4 attenuates secondary local and systemic inflammation processes and is associated with enhanced functional recovery after traumatic spinal cord injury in rats

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**Introduction:** Traumatic spinal cord injury (SCI) elicits a local and self-propagating systemic inflammation, limiting neuro-regeneration and contributing to lifelong disability and systemic complications. While experimental therapies focus on reducing the local inflammatory response, tackling systemic stress cascades following SCI could be a viable treatment approach as well. Because interleukin-4 (IL-4) is an anti-inflammatory immunomodulator, we aimed to decipher its effects after systemic application on functional recovery, local spinal cord and systemic inflammation upon SCI in rats.

**Methods:** 120 female Wistar rats were randomized to undergo either a laminectomy with a thoracic (Th10) clip compression SCI (IL-4, Placebo) or a laminectomy only (Sham). SCI animals then received IL-4 or placebo intraperitoneally twice daily for 7 days. Neurological function was assessed 3, 7, 14, 21 and 28 days post injury (dpi) via the CatWalk XT gait analysis, the BBB (Basso, Beattie, Bresnahan) openfield rating scale and the Gridwalk test (only at 28 dpi). Rats were sacrificed at different timepoints (1, 3, 7, 14 and 28 dpi) and immunohistochemistry (IHC) was used to assess neuroinflammation, cellular neurodegeneration, and astrogliosis of explanted and cryosectioned spinal cords. In

addition, protein and RNA levels of different cytokines were measured in the serum and peripheral organs via flow cytometry/RT-PCR to assess systemic inflammation.

**Results:** Rats with the IL-4 treatment bore significantly higher recovery of BBB scores compared to placebo-treated rats 14 and 28 dpi. In terms of hind limb function, the CatWalk XT gait analysis showed significantly higher recovery in IL-4 rats, peaking at 14 dpi. Furthermore, at 28 dpi, the IL-4 group demonstrated a lower rate of stepping-errors compared to the placebo group in the Gridwalk test. In IHC analyses, a significantly higher ratio of anti-inflammatory M2- to pro-inflammatory M1-macrophages was observed in IL-4 treated rats compared to placebo rats 3 and 7 dpi. Furthermore, astrogliosis was significantly reduced with the IL-4 treatment 28 dpi. In terms of systemic inflammation, placebo-treated SCI group showed significantly higher levels of pro-inflammatory serum cytokines compared to sham rats. With the IL-4 treatment, however, a strong reduction of those pro-inflammatory cytokines and an increase of anti-inflammatory cytokines could be observed in the acute to subacute post-injury phase.

**Conclusion:** Our findings establish an association between systemic IL-4 application and improved functional recovery after SCI in rats, possibly due to its local and systemic sub-acute anti-inflammatory effects. In addition, neuroinflammation and tissue scarring appear to be effectively reduced by said IL-4 application. Thus, IL-4 might be a promising treatment candidate for SCI and could be considered for further preclinical and ultimately translational studies.

#### SP 01

##### The role of sitting flexion radiography to detect lumbar instability – comparison with neutral standing x-ray and supine MRI

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**Objective:** The optimal imaging modality to detect lumbar instability remains controversial. Flexion-extension X-rays are often used in clinical practice, but have their limitations due to poor reproducibility and underestimation of segmental motion in symptomatic patients. Comparison of supine MRI scans with standing radiographs seems to have a higher sensitivity. We hypothesize that the use of a sitting flexion X-ray in addition to MRI/standing radiography offers a benefit to detect lumbar instability.

**Methods:** Retrospective analysis of adult patients with known lumbar spondylolisthesis (SL) who received a sitting flexion X-ray (FRad, Fig. 1) according to a standardized protocol in addition to routine standing neutral radiography (NRad) and supine lumbar MRI (SMRI) between 04/2020 and 12/2020. For every lumbar segment with a SL we calculated a ratio (slip percentage; SP) of anterior displacement relative to the length of the caudal vertebral body. The SP was compared between SMRI vs. NRad as well as SMRI vs. FRad to determine the rate of instable (≥8% difference) SL. Furthermore, the disc angle (DA; angle between inferior and superior end plates of the cephalad and caudal vertebral bodies) was measured. The presence of facet joint effusions on axial MRI was analyzed overall and in segments with instable SL.

**Results:** N=98 patients (f: n=50) with a median age of 73 years were included in the study. N=155 SL segments were analyzed; the most commonly affected segment was L4/5. The overall mean SP was 11.1%±6.5% in SMRI, 11.4%±6.7% in NRad, and 15.5%±7.2% in FRad (p=0.0001). An instable SL was detected in 9.7% of segments when SMRI and NRad was compared, and in 25.3% when SMRI was compared with FRad (p=0.0005). The overall mean DA (n=64 analyzed segments) was 6.4°±4.3° in SMRI, 6.8°±4.1° in NRad, and 3.5°±3.6° in FRad (p<0.0001). In 65% of segments facet joint effusion could be detected overall, and in 60% of patients with instable SL.

**Conclusion:** Sitting flexion radiography seems to offer a benefit in addition to comparison of neutral standing X-ray and supine MRI

in the detection of lumbar translational instability. Facet joint effusions did not correlate with instability in our cohort.

Fig. 1: Exemplary FRad imaging (left) and standardized setup (right)

Fig. 1



#### SP 02

##### Different techniques of minimally invasive computer-navigated osteosynthesis as a treatment of sacral fractures – a single center retrospective cohort study

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**Introduction:** The incidence of osteoporotic fractures of the sacrum is increasing due to the demographic change. With the evolution of computer navigation minimally invasive techniques became available. Aim of this study is to evaluate the surgical outcome and complication profile of minimally invasive computer navigated techniques in the treatment of fractures of the sacrum.

**Methods:** Records of all consecutive patients receiving minimally invasive computer-navigated osteosynthesis of fractures of the sacral bone between 2018–2021 were analyzed. Medical history, fracture morphology and etiology, clinical status and surgical as well as radiographic data of each patient were retrospectively assessed. Fractures were classified using the Fragility Fractures of the pelvis score (FFP). Patients were grouped according to the applied technique: (1.) monoportal iliosacral screws, 2.) biportal bilateral iliosacral screws, 3.) combination of 1.) and 2.). Endpoints were mobility at discharge and follow up visit, screw loosening and surgical revision rate.

**Results:** Mean age of the 128 patients included in this study was 81 years. Of the 103 (80.5%) female and 25 (19.5%) male patients 82 (64%) suffered from low and 7 (5.5%) from high energy trauma. A traumatic fractures were present in 39 (30.5%) cases. Accordingly, osteoporotic fractures were the main indication (94.5%). All patients suffered from immobilizing pain. Main fracture type was FFP2 (47%) followed by FFP3 (27%) and FFP4 (18%). 48 patients (35.5%) were included in group 1, 33 patients (29.8%) in group 2 and 47 patients (36.7%) in group 3. Overall average incision-suture time was 62min ranging from 30–140min (group 1: 52min (30–91min); group 2: 82min (45–140min); group 3: 62min (35–103min)). Scheduled 1-year follow up appointments were kept by 66.4%. Documented screw loosening occurred in 11 (9.4%) cases (group 1: 7 cases (14.6%); group 2: 2 cases (13.6%); group 3: 2 cases (6.4%)). Compared to preoperative status, mobility at discharge and at follow up was improved in 100% of patients. The overall revision rate was 6.25%.

**Discussion:** The different techniques of computer-navigated sacral fracture osteosynthesis presented here have proven to be safe and feasible minimally invasive procedures with an excellent postoperative outcome and a low overall complication rate. Concerning screw loosening during follow up, further investigation is required to identify risk factors.

#### SP 03

### 5-year outcomes for single-level total disc replacement with a novel viscoelastic artificial cervical disc compared to Anterior Cervical Discectomy and Fusion (ACDF)

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The M6-C Artificial Cervical Disc, with a compressible viscoelastic nuclear core and an annular structure, is substantially different from first generation articulating surface designs. The purpose of this evaluation is to report 5-year safety and effectiveness of the M6-C artificial cervical disc compared with ACDF.

A prospective, multicenter, controlled, IDE clinical trial is ongoing. 12 M6-C sites and 11 ACDF sites are participating in the study, with pre-operative assessments followed by assessments at 6 weeks, 3 months, 6 months, 1 year, and annually out to 10 years post-implantation. 160 M6-C and 189 ACDF subjects were enrolled. Study subjects presented with one-level symptomatic degenerative cervical radiculopathy, and received either M6-C or ACDF at a single level. The M6-C and ACDF cohorts were propensity matched. Follow-up assessments are planned out to 10-years post-op.

Neck Disability Index Scores are available for 106 M6-C and 93 ACDF subjects at 5 years. At 5 years post-op, M6-C subjects had a mean NDI score of 8.0 – significantly better than the mean of 18.0 observed in the ACDF group. M6-C subjects experienced a mean NDI improvement from baseline of 47.5 points at 5-years, compared to 33.4 for the ACDF cohort, significantly better for the M6-C group. At 5 years post-op, a statistically higher percentage of M6-C subjects experienced a 15-point improvement from baseline (98.1%) compared to the ACDF cohort (84.9%). Neck Pain and Shoulder/Arm Pain VAS Scores are available for analysis for 105 M6-C and 93 ACDF subjects at 5 years. At 5 years post-op, M6-C subjects had a mean Neck Pain VAS Score of 0.6, which was significantly better than the mean of 1.9 observed in the ACDF control group. M6-C subjects experienced a mean improvement from baseline of 6.5 points at 5-years post-op, compared to 5.1 for the ACDF cohort, significantly better for the M6-C group. Similarly significant results were observed in Shoulder/Arm Pain VAS Scores (worst side) at 5-years, with a mean of 0.5 for M6-C and 2.1 for ACDF, and a mean improvement from baseline of 6.8 for M6-C and 5.2 for ACDF. Through 5 years post-op, 5 M6-C subjects experienced Supplemental Surgical Interventions (SSI) at the index level. These included 3 Removals, 1 Reoperation, and 1 Supplemental Fixation. Of the removals, 2 were performed due to persistent neck and arm pain (with 1 being replaced by a new M6-C) and 1 was performed due to osteolysis associated with a confirmed infection. 11 ACDF subjects underwent SSIs through 5 years post-op.

The significant benefits associated with M6-C in earlier follow-up periods, compared to ACDF controls, appear to be maintained at 5-years post-op. SSI were lower in the M6-C group. When the M6-C was used at a single level, revisions for sterile osteolysis were not observed at 5-years post-op. The safety and performance of M6-C in this cohort will continue to be monitored out to 10-years post-op.

#### SP 04

##### Myelopathies related to dissections of the spinal dura

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**Introduction:** Dissections between inner and outer layer of the spinal dura are the result of a ventral defect of the inner dura layer leading to accumulation of cerebrospinal fluid (CSF) with the effect of a ventral compression of the spinal cord and development

of a myelopathy. Apart from traumatic injuries of the inner dura layer the etiology of this disorder is unclear. Large defects may lead to spinal cord herniations, while extensive dissections may cause spinal low pressure syndromes or superficial siderosis.

**Material/Methods:** 49 patients with dissections of the spinal dura were encountered since 2003, analyzed and followed prospectively. Males outnumbered females 2:1 with a mean age of 45+/-14 years and an average follow-up of 4 years. While the dissection was well demonstrated on MRI, localization of the defect in the inner dura layer for surgical planning required a postmyelographic CT in prone position. The clinical course was documented with scores for individual symptoms, rates for progression-free survival were determined by Kaplan-Meier-statistics.

**Results:** In 16 of 49 patients the dissection was combined with a spinal cord herniation into the underlying defect. In 18 patients the defect was the result of a traumatic incident. In patients with signs of a myelopathy, 27 operations aimed to close the dura defect, with reposition of a herniated spinal cord in 8 of these operations. A precise localization and sufficient closure of the defect required repeat operations in 4 patients. If the closure was successful, a collapse of the dissection was apparent on MRI within a few days after surgery. Postoperative improvements of a myelopathy were observed in 2 patients only, stabilization of the clinical course preventing a further deterioration was the commonest postoperative result for these patients. A progression-free survival for 10 years was obtained for 64% overall. If postoperative deteriorations were observed, they occurred within one year and indicated an insufficient closure of the defect. No dissection reappeared long-term once the defect had been closed sufficiently and the dissection had regressed on the initial postoperative MRI.

**Discussion:** Dissections of the spinal dura are a rare cause of myelopathy which tends to affect the thoracic cord predominantly as CSF accumulates between both dura layers over a long time resulting in ventral cord compression. Large defects may be associated with spinal cord herniation. Sustained stabilization of the clinical course requires the precise localization and sufficient closure of the defect in the inner dura layer and reposition of the spinal cord into its normal anatomical position in patients with associated spinal cord herniation.

#### SP 05

##### Results of a biomechanical pilot study to determine the ROM before and after dorsal correction spondylodesis by means of real-time three-dimensional representation using strain gauges

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**Introduction:** In a pilot study, the three-dimensional mobility of the lumbar spine is examined in real time (as a range-of-motion analysis, ROM, measurement in °) before and after posterior correction spondylodesis in patients with idiopathic adolescent scoliosis.

**Methods:** In this study, numerical values (ROM in °) of the lumbar spine in patients after dorsal correction spondylodesis are recorded in pre-/post-op and 1 year follow-up (1 YFU) comparison as well as in comparison to healthy volunteers over a period of 12 months. Inclusion and Exclusion Criteria

- Surgically treated patients between the ages of 10 and 18 years with idiopathic scoliosis and indication for surgery.
- Control group of healthy subjects aged 10-18 years with no spinal deformity

Biomechanical measurement and procedure Measurement with computer-assisted recording of the extent of movement in degrees of angle of the spine (ROM analysis) using flexible sensor strips with strain gauges. Here, flexion, extension, lateral flexion right and left and rotation right and left are recorded.

**Results:** At the current time there are 8 patients (5w, 3m) with an average age of 16.1 years in the group of preoperative measurements. In the 1 YFU there are currently 7 patients (4w,

3m) with an average age of 16.4 years. As of June 30, 2022, 15 subjects (average age 13.7 years) were included in the comparison group of healthy patients without spinal curvature.

	patient group					comparison group
	preOP (ROM in °)	postOP (ROM in °)	1 YFU (ROM in °)	Change pre OP - post OP in °	Change pre OP - 1 YFU in °	
<b>Flexion</b>	47	20	37	28	11	68
<b>Extension</b>	39	16	18	23	21	62
<b>Left Lateral Flexion</b>	32	12	26	20	6	41
<b>Right Lateral Flexion</b>	31	14	25	17	6	46
<b>Left Rotation</b>	38	12	23	26	16	43
<b>Right Rotation</b>	53	19	30	34	23	54

Immediately after the operation, there was a total reduction in mobility of around 60% (addition of all angle degrees). The rotation showed the greatest changes: left rotation -26°, right rotation -34°. At the one-year follow-up, a 34% reduction in ROM remained in angle addition. One year after the operation, the standing lordosis also showed a reduction, which averaged 5 degrees. In the follow-up after one year, a 34% reduction in the ROM remained in the angle addition. The comparison to healthy volunteers shows a difference especially in extension and flexion. Points of criticism are currently the small number of patients and subjects examined. The results are therefore to be regarded as preliminary. The measuring technology is also not yet ready for the market, but shows reproducible results.

Fig. 1

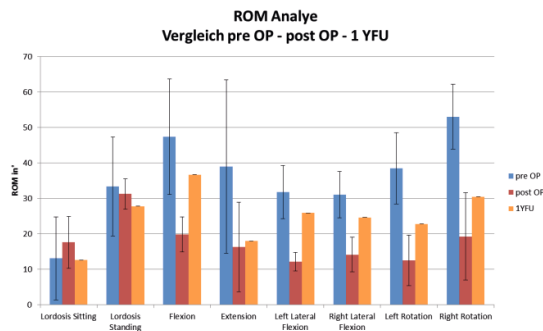
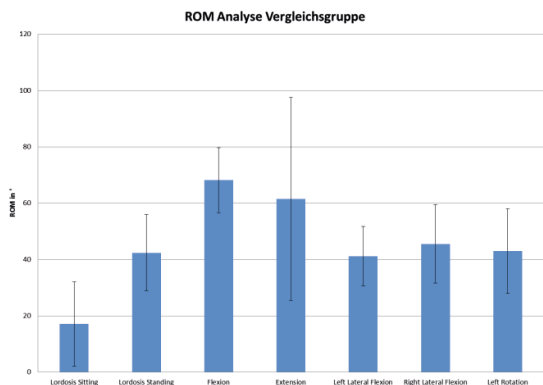


Fig. 2



SP 06

Quantification of cervical spinal stenosis by an automated 3D MRI segmentation algorithm

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**Objectives:** Imaging evaluation of cervical spinal stenosis is based on human subjective classification into poorly delineable categories in clinical routine. However, to reach accurate diagnosis and targeted treatment a more precise and reliable assessment is desirable. Thus, we investigated a fully automated quantification of spinal canal compromise based on 3D T2 MRI segmentation of the spinal cord and CSF volume in correlation with human subjective classification.

**Methods:** 114 symptomatic patients with predominantly mono-level stenosis and 88 healthy volunteers prospectively underwent 3D T2 SPACE MRI of the cervical spine. Based on a trained deep convolutional neuronal network, CSF space and spinal cord were segmented fully automated and the *adapted Maximal Canal Compromise* (aMCC) and *adapted Spinal Cord Occupation Ratio* (aSCOR) were calculated for all five cervical segments from C2 to C7. The evaluation procedure and score definition are depicted in Fig.1. Three independent experts performed subjective classification in *no stenosis*, *relative stenosis* and *absolute stenosis* for definition of the ground truth.

**Results:** Of in total 1010 segments evaluated, subjective grading showed no stenosis in 798 (79.0%), relative stenosis in 85 (8.4%) and absolute stenosis in 127 (12.6%) segments, revealing significantly different automatically computed aMCC and aSCOR values within these groups ( $p \leq 0.001$ , Fig.2). In a second step, we calculated cut-offs reaching optimal diagnostic accuracy for separation of no from relative spinal stenosis at an aMCC of 1.18 and aSCOR of 36.9%. For differentiation of relative and absolute stenosis, the parameters showed correspondingly higher cut-offs (aMCC=1.54, aSCOR=49.3%, Fig.2).

**Discussion:** This fully automated 3D MRI segmentation algorithm reached a high and reliable diagnostic accuracy for classification of cervical spinal stenosis. The calculated cut-offs can be used for radiological quantification of the severity of spinal stenosis in clinical routine. An advanced classification for a more detailed description of spinal stenosis based on these 3D anatomical data is now under investigation to improve the understanding of local pathophysiology and correlation to clinical affection.

**Figure 1:** Overview of the fully automated evaluation procedure from 3D T2 SPACE MRI (A), segmentation of spinal cord (yellow) and CSF space (green) with determination of the vertebral bodies (B) and calculation of CSF and spinal cord volumes at the middle third of each evaluated segment (white shaded rectangle, C). Right: formula for aMCC (CSF proportion of the index to both surrounding segments) and aSCOR (proportion of spinal cord and CSF at the index segment).

**Figure 2:** Boxplots for aMCC and aSCOR values. Comparison using Kruskal-Wallis test revealed significant differences between all evaluated groups ( $p \leq 0.05$ ). The cut-offs between groups (red rectangle) were determined by ROC analysis and calculation of Youden's index.

Fig. 1

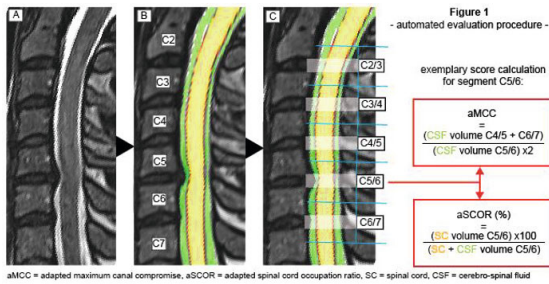
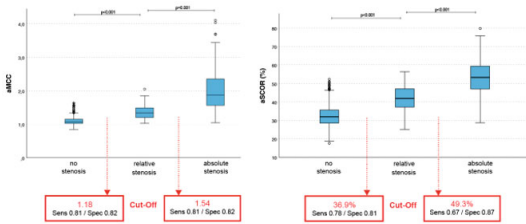


Fig. 2



SP 07

Evolution of the management of chronic noziceptive low back pain secondary to neuromuscular instability – pathology, patient identification and outcomes of patients treated with restorative neurostimulation (bilateral peripheral Motor-Nerve Stimulation at Ramus dorsalis L2)

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**Introduction:** Neuromuscular instability is a well-recognised cause of a specific phenotype of mechanical chronic low back pain (CLBP). Although the presentation often typified by the presence of degenerative changes to the multifidus, fatty and connective tissue infiltration are a consequence of neural and musculoskeletal processes in response to injury or degeneration. Neurological dysfunction occurs at central and peripheral structures, impacting proprioception and motor planning and structural changes occur in the muscle affecting endurance and coordination. Restorative neurostimulation has been employed to improve clinical outcomes in patients with this type of CLBP and has demonstrated effectiveness and durability in both clinical trials and clinical practice.

**Method:** A prospective registry of cases conducted in Germany was established as part of the post market requirements for the use of the ReActiv8 (Mainstay Medical, Dublin, Ireland) device in Europe. Here we review the experience of a single centre including guidelines for patient selection, post-operative care and rehabilitation and clinical outcomes, including numerical rating scale (NRS) for back pain, Oswestry disability index (ODI), quality of life (EQ-5D 5L). Patient selection is critical to ensuring reproducible outcomes and as such a three-step process was introduced; step 1 – detailed history with an emphasis on the activities that change pain levels, step 2 – a review of prior conservative management to ensure that high quality exercise and physical therapy has been completed and step 3 – physical assessment with the prone instability test and MRI review. As such patients were included at this site according to these criteria.

**Results:** At the time of submission 22/24 patients have completed 1 year of follow-up after screening through the three-step process. On average these patients had a median age of 52(23-82) years, with a median history of CLBP of 5 (0.5-31) years. At baseline Pain Numerical Rating Score (NRS) was 7.9 ± 0.2, Oswestry Disability Index (ODI) was 42.0±2.6 and EQ-5D-5L was 0.461±0.06. At follow up, Pain NRS was 3.3±0.5, ODI was 25.7±4.0 and EQ-5D-5L was 0.745±0.043. Additionally, 72% of

patients experienced a 50% or greater reduction in pain and 55% a more than 15-points improvement in ODI. With a restorative mechanism of action, it can be anticipated that these outcomes will continue to improve over the longer term.

**Discussion:** There is a select subset of CLBP patients that experience severe pain and disability resulting from neuromuscular instability. Restorative neurostimulation has demonstrated effectiveness and durability in multiple studies for these patients. These data show that through careful patient selection using a structured approach to ensure both appropriate pathology and failure of appropriate conservative management, that the real-world outcomes are equivalent to stringent RCT criteria and that these outcomes can be routinely obtained.

Fig. 1

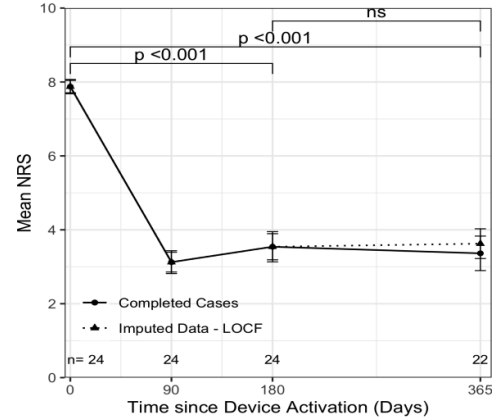
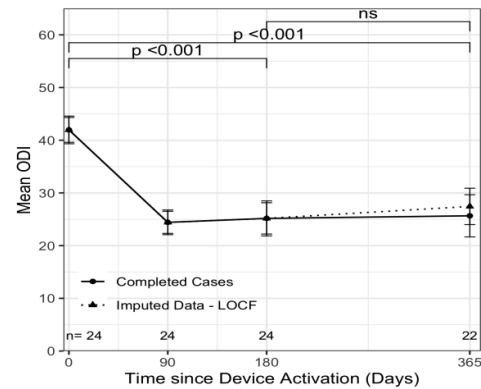


Fig. 2



SP 08

Systematic immunohistological analysis of age-related extracellular matrix changes in murine facet joints and intervertebral discs

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**Purpose:** With increasing age, the proteoglycan content is reduced and water is lost from the extracellular matrix (ECM) in both intervertebral discs and articular cartilage of facet joints. These changes alter the mechanical properties of the tissue and increase the susceptibility for its degeneration. Previous studies focused on collagens and proteoglycans, the two major ECM components. However, minor components that interconnect collagen fibrils, link the collagen network to the aggrecan matrix and determine functional properties have not been studied systematically.

The purpose of this study was to determine if there are any age specific changes in the expression and localization of these minor components.

**Methods:** Facet joints and intervertebral discs (n=5) were harvested from 6, 12 and 14 months old C57BL/6 mice. After decalcification, tissues were embedded in paraffin and sections of 5 µm were prepared. To visualize tissue morphology and proteoglycans, sections were stained with safranin-O. ECM components were detected with specific antibodies directed against collagen II, VI, IX, XII, thrombospondin-1, -4 and -5 (COMP), matrilin-2 and -3, nidogen-1 and -2, EMILIN-1 and decorin.

**Results and conclusion:** We observed distinct and tissue-specific changes in matrix protein expression and localization. In facet joints of older mice, reduced safranin-O staining indicated an expected proteoglycan loss. The expression of collagens II and IX was unchanged while collagen VI and XII expression increased. A higher staining intensity was detected for thrombospondin-4, -5, decorin, nidogen-1 and EMILIN-1 in older animals with the latter two exclusively found pericellularly. In the intervertebral disc, the staining intensity for all thrombospondins, matrilin-2, EMILIN-1 and nidogen-1 increased with ageing even though the staining for proteoglycans and all collagens was not obviously changed at the same time point. We detected age-related changes in expression and localization of minor ECM components prior to the degradation of the major suprastructures consisting of collagens and proteoglycans. The rearrangement and/or loss of minor interconnecting proteins might destabilize higher order structures in the ECM. This would explain altered mechanical properties and an increased susceptibility for tissue degeneration during ageing.

#### P 001

##### Compiling a risk profile for postoperative adverse events in surgery for lumbar spinal stenosis in octo- and nonagenarians

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**Objectives:** Lumbar spinal stenosis is a disease predominantly affecting older patients. An aging society increasingly demands continued mobility in old age. Demographic change is increasingly presenting a spinal surgeon with greater challenges in therapy. In this study, we therefore aimed to identify potential risk factors for the development of postoperative adverse events (PAE) after surgical treatment of lumbar spinal stenosis in elderly patients.

**Materials and Methods:** In this retrospective study we analyzed our institutional database for patient safety indicators (PSI), hospital-acquired conditions (HAC), and specific spine surgery complications (SSC) as high-quality measurement profiles for PAE in patients (≥80 years) who underwent surgery for lumbar spinal stenosis in our department between 2017 and 2021. Preoperative frailty was quantified using modified frailty index (mFI). Multivariate analysis was performed to identify independent predictors of the development of PAEs after surgery for lumbar spinal stenosis in the elderly.

**Results:** We identified 71 patients who underwent surgery for lumbar spinal stenosis at age ≥ 80 years. Overall, PAEs occurred in 25 % of cases. Additionally, we performed multivariate analysis revealed increased (preoperative) frailty (p=0.006) and prolonged duration of surgery (p=0.02) as independent significant predictors of PAEs in octo- and nonagenarians.

**Conclusion:** Knowledge of risk factors for postoperative complications will enable future prevention and optimal response, especially in vulnerable elderly patients. In the present study, increased frailty and prolonged duration of surgery were associated with PAEs in elderly patients with surgically treated lumbar spinal stenosis.

#### P 002

##### Biomechanical analysis of cage movement in 360° fixation during the early postoperative phase with osteoporosis

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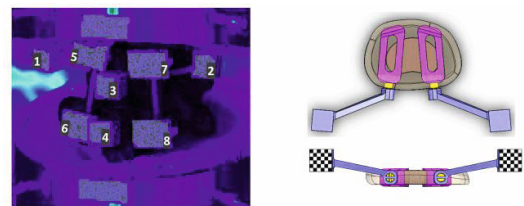
**Introduction:** A 360° fixation with a cage as ventral support and pedicle screw rod system as dorsal stabilization is a common surgical practice for fusion operations. Occasionally, the cage collapses into the vertebral body during the early postoperative phase, especially when osteoporosis is present. A possible factor could be translational and rotational movements of the cage along the vertebral body cover surfaces, which result in the cage penetrating through the cover surfaces. The aim of this study was to investigate these relative movements of two different cage designs.

**Methodology:** Fourteen cadavers, with L2/L3 and L4/L5 motion segments, mean age of 80.6 ± 9.14 years, and mean BMD of 0.95 ± 0.17 g/cm<sup>2</sup>, were dissected and instrumented with a 360° fixation. In a randomized manner, half of the specimens were fitted with two PLIF cages and the other half with one oblique cage. In order to measure the movement of the cages with an optical image correlation (DIC) system, 3D-printed markers were attached to the cages and guided outward through the foramina (figure 1). After embedding in resin, the motion segments were clamped in a multi-axis test rig and loaded with 30,000 cycles. The cycles resulted from 10,000 cycles each of extension-flexion (5Nm), lateral flexion (5Nm), and axial rotation (2Nm) at a constant axial compressive force of 60% of the body mass.

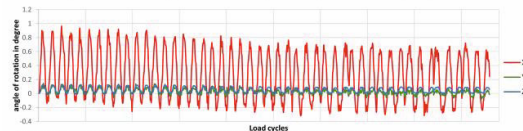
**Results:** Cage subsidence in the vertebral body was observed in only one specimen. Motion analysis showed that the cages significantly followed the initiated motion. During extension/flexion, they were rotating around the transversal axis by an average of 0.59° ± 0.27°. During lateral bending, the cages rotated around the sagittal axis by 1.02° ± 0.55° on average, and during torsion, they rotated 0.47° ± 0.43° around the longitudinal axis. A significant difference between oblique cage designs and PLIF cages could not be found.

**Conclusion:** The movements of the cages could be measured with this new methodology using DIC. The main direction of movement of the cages within a movement cycle was consistent with the initiated movement. Thus, the largest rotational movement occurred during lateral bending, which corresponds to the longitudinal axis of the cages, especially for the PLIF cages, which seem to be particularly sensitive for tilting. This presented method seems to be suitable for further investigation of the mechanisms of cage subsidence, although loads or loading cycles would need to be increased to provoke a sufficient number of cage subsidences for further conclusions.

Fig. 1

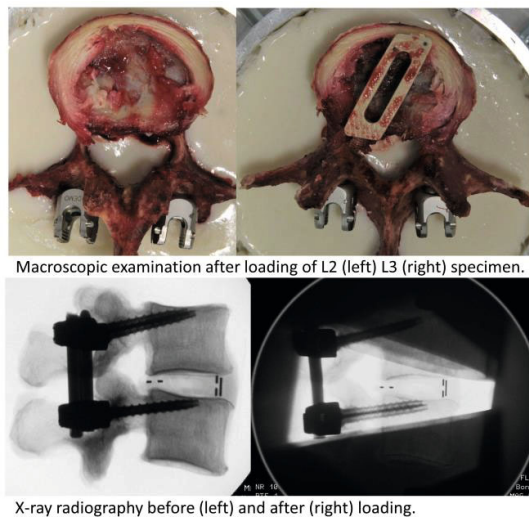


Test setup to measure cage motion via digital image correlation (DIC).



Typical rotation of a cage during 10,000 cycles of flexion / extension. 60 frames were acquired at cycles 10, 20, 50, 100, 200, 500, 1k, 2k, 3k, 4k, 5k, 6k, 7k, 8k, 9k, 10k, each.

Fig. 2



## P 003

### Surgical treatment of osteoporotic fractures using kyphoplasty: Is quattroplasty superior to the technique with single balloons?

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Vertebral compression fractures (VCFs) are a very common medical problem and describe the axial collapse of a vertebral body (VB) in the spine. The leading cause for VCFs is osteoporosis, leading to reduced bone stiffness. In case of therapy-resistant symptoms under conservative treatment, balloon kyphoplasty is a frequently used surgical treatment option. Therefore, a working trocar is first introduced transpedicularly into the fractured VB. Subsequently, a cavity is created with a balloon and filled with cement after balloon removal. The gold standard is the use of one balloon per side. The quattroplasty (see figure 1) is a newly developed technique, in which 4 balloons are available per VB, allowing to treat the anterior and the posterior part of the VB separately. The aim of quattroplasty is to achieve a superior straightening of the vertebral body, especially the anterior part and to gain a superior restorage the sagittal profile, compared to the single balloon technique.

In the presented study, 30 patients were treated with quattroplasty and radiological parameters (anterior vertebral body height (fig. 2A), kyphotic angle (fig. 2B)) as well as clinical scores (pain score (VAS), functional score (Oswestry disability index (ODI))) were recorded prospectively before and after surgery. These patients were compared to 30 patients who were treated with the single balloon technique and whose data were recorded retrospectively.

In a group comparison, the quattroplasty group (QG) showed a 2 mm better straightening of the anterior vertebral body height ( $p=0.03$ ) compared to the single-balloon group (SBG). Furthermore, the improvement of the kyphotic angle in the QG was superior to that in the SBG by an average of  $3.2^\circ$  ( $p=0.002$ ). Analysing the pain score over all study participants ( $n = 60$ ), the values demonstrated an improvement from VAS = 7.8 before surgery to VAS = 2 after surgery ( $p < 0.001$ ). The ODI also improved significantly from an average of 58 before surgery to 34 after surgery ( $p < 0.001$ ). In a group comparison, the mean decrease in pain score in the QG was 5.8, in the SBG only 3.5 ( $p=0.049$ ). The improvement of the ODI differed not significantly in the group comparison, averaging 27.6 in the QG and 23 in the SBG.

Both procedures lead to a significant pain reduction and improvement in functional score in patients with osteoporotic vertebral body fractures, appearing quattroplasty to be slightly

superior in terms of both radiological parameters and clinical scores.

Fig. 1

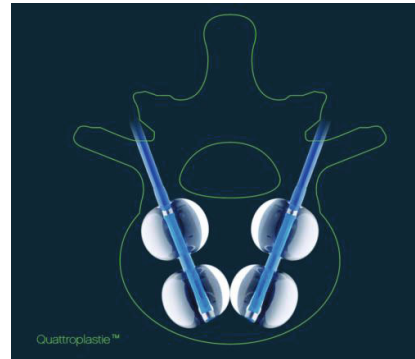
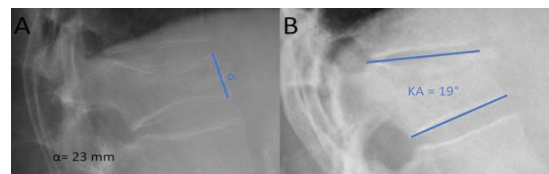


Fig. 2



## P 004

### The impact of osteoporosis on long-term outcome in lumbar spine instrumentation – preliminary results from the OsteoSpine database

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**Introduction:** Spinal instrumentation is increasingly confronted with mechanical complications (MC) requiring revision surgery due to its growing use in elderly and osteoporotic patients. Little attention has been paid to the underlying diseases of these patients. The aim of this work is to define and evaluate preoperative risk factors for the emergence of MC with special focus on bone quality.

**Material/Methods:** A retrospective cohort of 538 patients treated with lumbar instrumentation was recruited for this retrospective study. In addition to possible patient-related risk factors (BMI, age, previous disease, premedication), preoperative CT-measured bone density (BMDCT, measured as mean HU values of lumbar vertebral trabecular bone L1-5 in axial CT-scans) was assessed. The primary endpoint was defined as any form of mechanical complication in the 2-year postoperative course.

**Results:** We were able to include 195 patients (84 men, 111 women) for this retrospective analysis. 343 patients were excluded due to insufficient imaging or clinical follow up data. The median age was 60 years. There were significantly lower BMDCT values for patients with diabetes ( $p=0.003$ ), COPD ( $p=0.036$ ), previous stroke ( $p=0.049$ ), smoking history ( $p<0.001$ ) and patients with a combination of the upper mentioned diseases ( $p=0.001$ ). Intake of proton pump inhibitors ( $p=0.025$ ), glucocorticoids ( $p=0.05$ ), SSRIs ( $p=0.014$ ), and diuretics ( $p=0.04$ ) lowered BMDCT compared to patients without these drugs. Patients with increased BMI suffered significantly more often from screw loosening ( $p=0.024$ ) while postoperative insufficiency fractures were significantly more often found in patients with decreased BMDCT ( $p=0.043$ ).

**Discussion:** Multiple pre-existing conditions and premedication of patients scheduled for spine surgery can have a significant impact on the postoperative outcome. In the end, these factors may influence bone quality leading to a reduced bone-screw anchorage. A preoperative evaluation and removal of possible reversible factors may lead to reduced MC. Therefore, bone densitometry using lumbar CT scans is an efficient method for a rough evaluation of osseous quality.



**P 005****Mediating medical comorbidities in geriatric patients undergoing surgery for OVCF – from preoperative screening to risk and outcomes optimization**\*M. J. Scheyerer<sup>1</sup>, M. Lenz<sup>2</sup>, C. Jakobs<sup>3</sup>, M. Pumberger<sup>4</sup>, U. Spiegl<sup>5</sup>, B. W. Ullrich<sup>6</sup>, N. H. von der Höh<sup>5</sup>, K. J. Schnake<sup>7</sup><sup>1</sup>Universitätsklinikum Düsseldorf, Klinik für Orthopädie und Unfallchirurgie, Düsseldorf, Deutschland<sup>2</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>3</sup>St. Remigius Hospital Leverkusen, Wirbelsäulenzentrum, Leverkusen, Deutschland<sup>4</sup>Charité – Universitätsmedizin Berlin, Centrum für Muskuloskeletale Chirurgie (CMSC), Berlin, Deutschland<sup>5</sup>Universitätsklinikum Leipzig, Klinik für Orthopädie, Unfallchirurgie und Plastische Chirurgie, Leipzig, Deutschland<sup>6</sup>BG Klinikum Bergmannstrost Halle, Unfall- und Wiederherstellungschirurgie, Halle a. d. S., Deutschland<sup>7</sup>Malteser Waldkrankenhaus St. Marien, Interdisziplinäres Zentrum für Wirbelsäulen- und Skoliotherapie, Erlangen, Deutschland

**Introduction:** Osteoporotic vertebral compression fractures (OVCF) are a common increasing entity in elderly patients and represent a tremendous economic burden. Surgical treatment is related to high complication rates and little is known about patient-specific and internal risk factors associated with poor clinical results.

**Methods:** We carried out a comprehensive, systematic literature search according to the PRISMA checklist and algorithm. Risk factors for perioperative complications, for early inpatient readmission, for the duration of the hospital stay, the hospital mortality, the total mortality and the clinical result were analyzed.

**Results:** A total of 739 potentially usable studies were identified. After considering all inclusion and exclusion criteria, 15 studies with 15,515 patients were included. Non-adjustable risk factors were age >90 years (OR 3.27), male gender (OR 1.41), BMI less than 18.5 kg/m<sup>2</sup> (OR 3.97), ASA score >3 (OR 2.7), activity of daily live (ADL) (OR 1.52), dependence (OR 5.68), inpatient admission status (OR 3.22), Parkinson disease (OR 3.63) and disseminated cancer (OR 2.98). Adjustable factors were insufficient kidney function (GFR <60 ml/min, and Creatinine Clearance below 60 mg/dl) (OR 4.4), nutrition status (hypalbuminemia (< 3.5 g/dl)), liver function (OR 8.9) and further cardiac and pulmonary comorbidities.

**Discussion:** We identified a couple of non-adjustable risk factors, which should be considered preoperatively in terms of risk assessment. However, even more important were adjustable factors that can be influenced preoperatively. In conclusion, we recommend a perioperative interdisciplinary cooperation, especially with geriatricians, to achieve the best possible clinical results in geriatric patients undergoing surgery for OVCF.

**P 006****Lumbar decompression versus decompression and fusion in octogenarians – complications and clinical course with 3-year follow-up**\*P. Lenga<sup>1</sup>, G. Gülec<sup>1</sup>, A. Bajwa<sup>1</sup>, M. Issa<sup>1</sup>, K. Kiening<sup>1</sup>, A. W. Unterberg<sup>1</sup>, R. J. Oskouian<sup>2</sup>, J. R. Chapman<sup>2</sup>, B. Ishak<sup>1</sup>, B. Ishak<sup>1</sup><sup>1</sup>Universitätsklinikum Heidelberg, Klinik für Neurochirurgie, Heidelberg, Deutschland<sup>2</sup>Swedish Neuroscience Institute, Washington, DC, Vereinigte Staaten

**Introduction:** Over the past years, the prevalence of degenerative disorders of the lumbar spine, such as spinal stenosis and spondylolisthesis, has rapidly increased worldwide in the geriatric population. However, there is still a paucity of data describing the risk factors as well as mortality and morbidity rates of geriatric lumbar spinal surgery. Therefore, we aimed to assess and compare the clinical outcomes and complications (between surgical decompression only versus decompression and fusion in the lumbar spine in patients aged ≥ 80 years.

**Methods:** A retrospective review of electronic medical records at a single institution was conducted between September 2005 and December 2021. Data of patient demographics, surgical characteristics, complications, hospital clinical course, and 90-day mortality were collected. Comorbidities were assessed using the age-adjusted Charlson comorbidity index (CCI). Logistic regression was used to identify potential risk factors for the occurrence of complications.

**Results:** Over a 16-year period, 327 patients were allocated to the decompression only group, whereas 89 patients were allocated to the decompression and instrumented fusion group, with a mean follow-up duration of 36.7 ± 12.4 months. Patients of the instrumentation group were significantly younger than their counterparts (82.5 ± 2.5 years vs. 81.7 ± 1.4 years; p=0.049). When assessing the CCI, patients of the instrumentation group had fewer comorbidities (CCI 6.2 ± 1.5 vs. 8.9 ± 0.5; p<0.001), significantly longer surgical duration (290 ± 106 min vs. 145 ± 50.2 min; p<0.001), significantly higher volume of intraoperative blood loss (791 ± 319.3 ml vs. 336.1 ± 150.8 ml; p<0.001), more frequent intraoperative blood transfusion (7 ± 2.1% vs. 16 ± 18.0%; p<0.001), and extended stays in the intensive care unit and hospitalization rates. However, the in-hospital and 90-day mortality rates were similar in both groups. In-hospital revision rates were significantly higher in the instrumentation group, whereas in the long-term follow-up, no additional surgery was performed in either group. Logistic regression analysis revealed that surgical duration and extent of surgery were unique risk factors for the occurrence of complications.

**Discussion:** Lumbar decompression only, and additional fusion in octogenarians can safely be performed. Older patients undergoing lumbar spine fusion have longer hospitalization rates and higher revision rates than those undergoing decompression only. However, the mortality rates and neurological outcomes were similar in both groups. Prolonged operative time and extent of surgery are associated with a higher risk of complications. Careful attention to patients' comorbidities is critical, and use of an anesthetic and operative duration should be kept to a minimum.

**P 007****Spinopelvic parameters in fragility fractures of the pelvis**\*M. Lodde<sup>1,2</sup>, O. Riesenbeck<sup>1</sup>, D. Günes<sup>2</sup>, M. Schneider<sup>2</sup>, J. Kösters<sup>2</sup>, S. Schmeil<sup>2</sup>, P. Salmen<sup>2</sup>, T. Fischer<sup>2</sup>, M. J. Raschke<sup>1</sup>, U. Liljenqvist<sup>2</sup><sup>1</sup>Universitätsklinikum Münster, Klinik für Unfall-, Hand und Wiederherstellungschirurgie, Münster, Deutschland<sup>2</sup>St. Franziskus Hospital Münster, Klinik für Wirbelsäulenchirurgie und Skoliozentrum, Münster, Deutschland

**Introduction:** The incidence of fragility fractures of the pelvis (FFP) increased substantially during the last years [4]. FFP occur after low energy trauma and are associated with osteoporotic bone [4]. Spinopelvic parameter determining the sagittal balance are lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS) and lumbar lordosis index (LLI). In the present study the spinopelvic parameters in insufficiency fractures of the pelvis are examined.

**Methods:** All patients treated for FFP in a center of maximal care of the German Spine Society (DWG) between 2017-2021 were included. Inclusion criteria of this retrospective study are FFP, age > 60 years, low energy trauma, radiography of the lumbar spine and femoral heads and a CT or MRI. The following parameters were determined: LL, PT, SS, PI, LLI.

**Results:** 57 patients were included. The median LL (49.1°) and the median PI (61.6°) were significantly different (p<0.001). The median difference of LL and PI is 12.5°. The median PT is 28.7° and the median SS is 33.3°. The LLI is 0.74. Figure 1 shows the boxplots of LL (median 49.1°) and of PI (median 61.6°).

Figure 2 shows two examples of measurement of the spinopelvic parameters LL, PI, PT, SS.

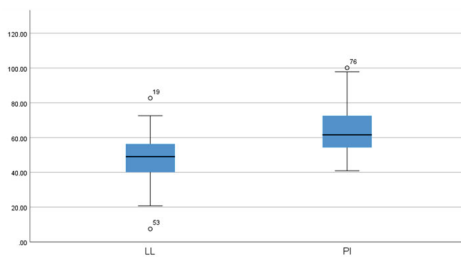
**Discussion:** Compared to the published values of Schwab, LeHuec and Barrey-Roussouly the PI (61.6°) is increased. The measured LL (49.1°) is reduced. An increased PI correlates with isthmus spondylolisthesis [1], leads to a concentration of stress at the L5-S1

junction, [5] and correlates with osteoporosis [3]. A reduced LL is a risk factor for subchondral insufficiency fractures of the femoral head[2]. The results of the present study show that an increased PI and a reduced LL might be a risk factor for FFP.

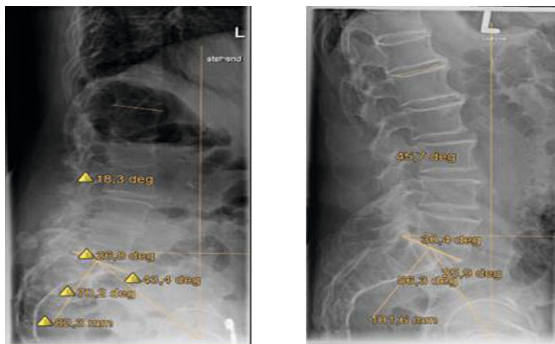
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**Fig. 1**



**Fig. 2**



#### P 008

##### Treatment and outcome of dens fractures with accompanying atlanto-axial instability

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**Introduction:** The number of dens fractures in the population is steadily increasing (1). Especially for dens fractures with accompanying atlantoaxial instability, different therapeutic strategies can be found in the current literature (2, 3, 4). Both conservative and surgical treatment (ventral screw osteosynthesis, dorsal instrumentation) are associated with complications (4).

The aim of the present study is to compare complications and outcome of patients with dens fracture and atlantoaxial instability.

**Material/Methodology:** The study was performed from 2012 to 2017 with the following inclusion criteria: (I) Dens fracture type II according to Anderson and D'Alonzo (5), (II) age  $\geq 65$ , (III) severe atlantoaxial instability with a C2 uncovering (C2U) of  $>50\%$  according to Evaniew (4). Here, the C2U is defined as the size of the exposed cranial articular surface of the axis (4). Three groups were compared: conservative treatment ("conservative group"), surgical therapy with ventral screw osteosynthesis ("ventral group"), and surgical therapy via dorsal instrumentation ("dorsal group").

Concomitant injuries and patient condition were considered in therapy selection. Patient demographics and neurologic status were collected. Length of hospital stay and duration of surgery were also recorded. Treatment, complications, and clinical outcome of patients were analyzed. Range-of-motion (ROM) was evaluated.

**Results:** 39 patients could be included. Patients from the "dorsal group" were hospitalized significantly longer (14.5 days) than patients from the other groups ("ventral group": 11 days, "conservative group": 5 days). There was no significant difference in complications between the three groups.

A total of 25 patients could be followed up (study period: 5.2 months). There was no significant difference in motion assessment between the groups. Pain was mainly reported by surgically treated patients: "ventral group" 60.0%, "dorsal group" 45.5%, "conservative group" 11.1%. Neurological deficits were present in 11.1%, 0.0%, and 27.3% ("conservative group", "ventral group" and "dorsal group"). There was a pseudarthrosis rate of 8%. Pseudarthrosis occurred most frequently in the "dorsal group" (9.1%). No pseudarthrosis occurred in the patients of the "conservative group".

**Discussion:** Patients with a dens fracture and accompanying atlantoaxial instability require individualized treatment planning. The complications and outcome of different treatment modalities should be considered.

#### Literature

- (1) Smith et al, 2010, *J Spinal Disord*
- (2) Leitlinie Verletzungen der oberen HWS, DGU
- (3) Iyer et al, 2018; *Neurosurgery*
- (4) Evaniew et al, 2015, *The Spine Journal*
- (5) Anderson et al, 1974, *The Journal of Bone and Joint Surgery*

#### P 009

##### Digital neurocognitive monitoring in patients undergoing opioid pain medication after spinal surgery – a feasibility study

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**Introduction:** Patients undergoing spinal surgery usually require postoperative pain management to alleviate wound pain. Pain medication includes WHO grade 1 analgesic but also potent opioids, potentially leading to severe side effects such as fatigue, nausea and cognitive decline. Up to now, the cognitive impairment due to postoperative pain protocols is only poorly studied and objective measures would help to adapt the dose optimally.

**Material/ Methods:** We performed a prospective monocenter feasibility study enrolling patients before undergoing spinal surgery. Cognitive testing was performed using a tablet-based application before surgery (baseline), as well as on day 2 after surgery (intravenous opioids), before discharge (oral opioids) and at follow-up. We recorded the exact pain medication and other side effects from the medication. Potential risk factors for postoperative decline in cognition were age, high-dosed opioid application, length of surgery and blood loss.

**Results:** We included 20 patients in our study. Median age was 67 years. Baseline assessment revealed no cognitive impairment before surgery. All patients underwent a dorsal instrumentation in our neurosurgical department for degenerative (60%), osteoporotic fracture (15%) or tumor (25%) indication. Cognitive testing after surgery showed a significant decline under intravenous opioid therapy including short time and delayed recall word listing (8 vs. 4 words) as well as logic testing including arithmetic fluency

(number ordering time 23 vs. 41 seconds) ( $p < 0.001$ ). Cognitive performance significantly improved with recovery until follow-up and opioid discontinuation.

**Diskussion:** Cognitive assessment in patients undergoing spinal surgery with postoperative opioid medication revealed a postoperative impairment under intravenous medication. Such side effects should be monitored closely, and cognitive decline should be considered for dosage adaption.

**P 010**

**The outcome of conservatively treated thoracolumbar fractures of type A3 of the AO classification in comparison to surgically treated patients**

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**Introduction:** The question whether surgical or conservative treatment of type A3 spinal fractures of the AO classification in the thoracolumbar region achieves better results with regard to pain and functional limitations is still controversial. The literature to date does not allow a clear conclusion and the question remains as to which factors influence healing and its outcome. It is therefore relevant to compare these two groups of patients in order to draw a conclusion on the choice of the best possible therapy.

**Material/Method:** Included were 64 patients with a vertebral fracture in the thoracolumbar region Th10-L4 of type A3 of the AO classification, who were at least 18 years old at the time of the accident and had a follow-up at our clinic beyond 3 months after the accident. Of these, 26 were treated conservatively, representing 40.6%, and 38 surgically, representing 59.4%, at our clinic from 2004 to 2018.

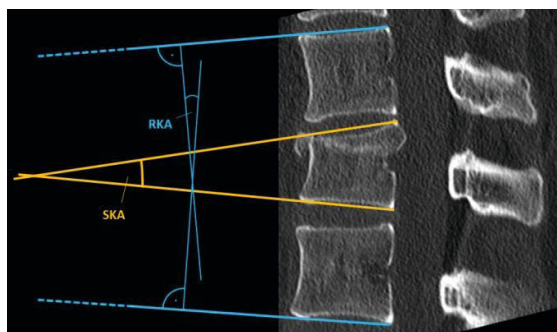
The two groups were compared in terms of segmental (SKA) and regional kyphotic angle (RKA) using radiological imaging on the day of the accident and at follow-up, and pain (VAS) and functional impairment (ODI) documented in the medical history at follow-up using T-test and Mann-Whitney U-test. Patients with osteoporosis and neurological deficits, and those with a final follow-up shorter than 3 months were excluded.

**Results:** A significant difference between the two groups was shown by T-test in the improvement of SKA (95% confidence interval, -11.408 to -5.429,  $p < 0.001$ ) and RKA (95% confidence interval, -11.228 to -3.308,  $p < 0.001$ ) from the time of the accident to the follow-up and in the absolute degrees of SKA at follow-up (95% confidence interval, 4.565 to 10.911,  $p < 0.001$ ).

Pain, functional limitation, and RKA at follow-up did not show significant differences. Neither for the whole study population nor compared within the age groups 18a-49a and  $\geq 50a$ .

**Discussion:** The results show that although SKA and RKA improve significantly more in the course after surgery, compared to conservative therapy, this does not bring any advantage regarding pain and functional limitation compared to the conservative group. This suggests that the focus of therapy selection should not primarily be focused on the severity of the wedge vertebrae formation, but that other factors, such as age, bone quality, and previous internal diseases, may play a more important role in the healing process.

**Fig. 1**



**Fig. 2**

	T-Test		Mann-Whitney-U-Test
	Signifikanzniveau (2-seitig)	95% Konfidenzintervall	
<b>Gesamtes Studienkollektiv</b>			
SKA1-SKA2	$p < 0,001$	-11,408 bis -5,429	
RKA1-RKA2	$p < 0,001$	-11,228 bis -3,308	
SKA2	$p < 0,001$	4,565 bis 10,911	
RKA2	$p = 0,419$	-3,658 bis 8,677	
Schmerzen			$p = 0,498$
Funktion			$p = 0,227$
<b>18a-49a</b>			
SKA1-SKA2	$p = 0,007$	-8,413 bis -1,517	
RKA1-RKA2	$p = 0,651$	-12,145 bis 7,760	
SKA2	$p = 0,013$	2,048 bis 15,573	
RKA2	$p = 0,102$	-2,208 bis 22,618	
Schmerzen			$p = 0,286$
Funktion			$p = 0,250$
<b><math>\geq 50a</math></b>			
SKA1-SKA2	$p < 0,001$	-11,890 bis -4,960	
RKA1-RKA2	$p = 0,007$	-11,286 bis -1,861	
SKA2	$p = 0,012$	1,372 bis 10,554	
RKA2	$p = 0,455$	-11,398 bis 5,195	
Schmerzen			$p = 0,758$
Funktion			$p = 0,696$

**P 011**

**Functional outcome after initial and multiple intramedullary hemorrhage in conservatively treated patients with spinal cavernous malformations**

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**Background and Purpose:** To investigate the natural course and to assess predictors of functional outcome in spinal cavernous malformation (SCM) patients with unique or multiple intramedullary hemorrhage (IMH) events.

**Methods:** Inclusion regarded conservatively treated SCM patients with complete clinical baseline characteristics, magnetic resonance imaging dataset,  $\geq 1$  SCM-related IMH and  $\geq 1$  follow-up examination treated between 2003 and 2022. Neurological functional status was obtained using the modified McCormick scale at diagnosis, before and after each IMH, as well as at last follow-up.

**Results:** 45 patients with SCM-related IMH were analyzed. Univariate analysis identified multiple bleeding events (OR = 15.28, 95% CI = 3.22-72.47,  $P < 0.001$ ) to be the only statistically significant predictor for an unfavorable functional outcome at last follow-up. Patients significantly deteriorated after first bleeding (85.7%,  $P = 0.001$ ) and even more after second bleeding (92.8%,  $P = 0.005$ ). Time between last IMH and last follow-up did not influence this outcome.

**Conclusions:** IMH due to SCM is linked to functional neurological worsening. Such outcome tends to improve after each hemorrhage, but with every bleeding event the probability of full recovery declines.

**Fig. 1**

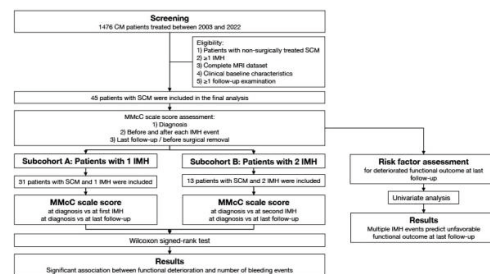
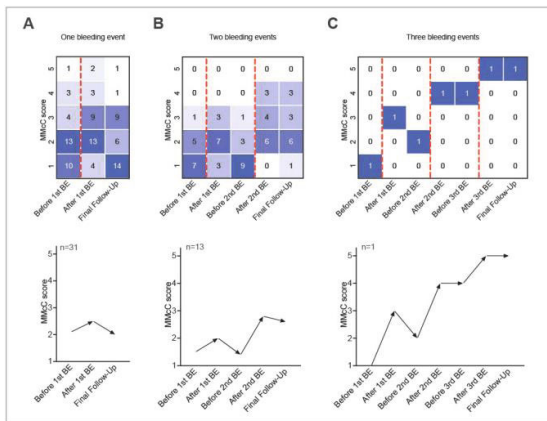


Fig. 2



## P 012

## Investigation to record neuromuscular control using CoP track and frequency

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**Background:** The gold standard method for assessing trunk neuromuscular control is to measure postural control. The measure commonly used is the distance traveled by the center of body pressure (CoP track). However, the CoP track is subject to significant floor and ceiling effects in some cases. A more accurate measure to quantify trunk neuromuscular control might be to look at power turnover in selective power density (PSD) aspects. It is known that in PSD different functional areas (e.g. lower extremities or trunk) can be assigned.

**Methods:** 66 healthy volunteers (19–58 years) participated in the prospective study and were examined in a DOSB-licensed sports medicine department in 2021. Measurements were performed with a modified Wii balance board (Germany) in sitting and in double-legged stance for 60 seconds in randomized order. The sampling rate was 1 kHz at 14-bit quantization using a third-order Butterworth low-pass filter with a cutoff frequency of 14 Hz. Pearson correlation coefficients between the CoP track and power conversion (area under the spectrum), measured in standing (ST) and sitting (SI), within different frequency ranges throughout the frequency spectrum between 0.01 and 10 Hz were evaluated. The series of measurements were filtered with a cutoff frequency of 14 Hz, for this reason the observation up to 10 Hz was chosen, since above this a possible attenuation of the frequencies by the filter may be present. In addition, the known functional frequency ranges are below 10 Hz. The description of the data was based on mean and standard deviation. Correlation was analyzed with a significance level of  $p \leq 0.05$ .

**Results:** For subjects composed of 34 females and 32 males with a mean age of 28.6 years (SD  $\pm$  7.7 years), a mean height of 175.4 cm (SD  $\pm$  9.7 cm), and a mean weight of 72.2 kg (SD  $\pm$  15.4 kg), the correlations between the CoP track and power conversion in the PSD were as follows. Frequency spectrum; 0.01–10 Hz ( $r_{ST}=0.501$ /  $r_{SI}=0.514$ ), 0.01–4 Hz ( $r_{ST}=0.625$ /  $r_{SI}=0.451$ ), 4–10 Hz ( $r_{ST}=0.486$ /  $r_{SI}=0.809$ ).

**Discussion:** The present study demonstrates comparative measurements between the CoP track and power turnover in selective frequency spectra. It shows that depending on the body

part, the highest correlations are in different frequency ranges. In particular, for the quantification of neuromuscular control of the trunk, the evaluation of the frequency spectrum between 4–10 Hz seems to be an alternative measure compared to the CoP track evaluation. Further investigations of the power turnover in back pain patients, e.g. before and after a trunk stabilizing training measure seem to be useful to investigate the sensitivity of this measurement method.

## P 013

## Marked increase of cross-sectional area and improvement of muscle quality in m. multifidus after a medical strengthening therapy based on isolated lumbar extension resistance exercise in patients with lumbar disk pathologies and radiculopathy

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**Introduction:** Pronounced muscle atrophy and local fat infiltration in the deep paraspinal lumbar extensor muscles, especially in the multifidus muscle, are common morphological changes in patients with specific and unspecific chronic low back pain conditions [1]. Pain related avoidance behavior mechanisms lead to decreased motor control function which causes increased degeneration of the disks and facet joints. There are promising treatment options such as machine based heavy loaded isolated lumbar extension resistance exercise (ILEX) [2] that have shown very good outcomes on subjective pain symptoms and strength increase. However, there is so scarce knowledge on the effects of those exercise therapies on paraspinal structure and if the process of atrophy and fat infiltration can be reversed.

**Material/Methods:** This pilot case series represents seven consecutive male patients (age range 29–70) with disc herniations/protrusions, spondylarthritis and radiculopathies who underwent an ILEX-based exercise intervention program consisting of 25 exercise sessions (ES) with 18 ES 2x/week and seven additional ES 1x/week. Range of Motion (ROM) was limited in order to protect passive structures. Before and after the treatment MRI was taken and analyzed muscle quality (cross sectional area (CSA), lean muscle mass (LM), fat fraction (FF)) of m. multifidus for both sides (r/l) in three lumbar spinal segments L3, L4 and L5.

**Results:** The total CSA (in cm<sup>2</sup>) increased at all analyzed segments between 7.17 and 8.99 % (L3: 7.86 (mean)  $\pm$  2.03 (SD) (pre) vs. 8.57  $\pm$  2.15 (post),  $p < 0.001$ ; L4: 10.19  $\pm$  1.04 (pre) vs. 10.94  $\pm$  1.18 (post),  $p < 0.001$ ; L5: 11.06  $\pm$  0.80 (pre) vs. 11.85  $\pm$  0.81 (post),  $p < 0.001$ ). LM (in cm<sup>2</sup>) increased between 11.02 and 12.43 % (L3: 6.68  $\pm$  1.94 (pre) vs. 7.41  $\pm$  2.05 (post),  $p < 0.05$ ; L4: 8.11  $\pm$  0.83 (pre) vs. 9.07  $\pm$  0.96 (post),  $p < 0.01$ ; L5: 8.85  $\pm$  0.98 (pre) vs. 9.95  $\pm$  0.85 (post),  $p < 0.05$ ). Concerning FF (in %) there was a reduction of 14.46 to 20.04% (L3: 16.05  $\pm$  7.05 (pre) vs. 13.73  $\pm$  6.01 (post),  $p = 0.24$ ; L4: 20.05  $\pm$  6.75 (pre) vs. 16.86  $\pm$  5.79 (post),  $p < 0.01$ ; L5: 19.96  $\pm$  8.57 (pre) vs. 15.96  $\pm$  5.29 (post),  $p < 0.05$ ).

**Discussion:** Heavy loaded ILEX leads apart from reduction of pain symptoms also to a marked improvement in morphology of m. multifidus and is therefore a promising treatment option for patients with specific spinal disorders. Furthermore, it can be potentially used for delaying age-related muscle atrophy and for maintaining spinal health. To the best of our knowledge, this is one of the first studies comparing quality of m. multifidus pre and post exercise intervention through MRI measurements. Further studies with larger patient groups are being designed at the moment.

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[2] Steele J, Bruce-Low S, Smith D. PM R. 2015;7(2):169-87.

## P 014

**Neuromodulation by transcranial magnetic stimulation (TMS) for the treatment of chronic low back pain**S. Freigang<sup>1</sup>, \*C. Lehner<sup>1</sup>, S. Kurschel-Lackner<sup>1</sup>, M. Mokry<sup>1</sup>, S. Fresnoza<sup>2</sup>, K. Zaar<sup>1,2</sup>, B. Sutter<sup>1</sup><sup>1</sup>Medizinische Universität Graz, Klinik für Neurochirurgie, Graz, Österreich<sup>2</sup>Karl-Franzens-Universität Graz, Institut für Psychologie, Graz, Österreich

**Introduction:** Despite effective surgical treatments, chronic low back pain (cLBP) remains a major burden of our society. Repetitive transcranial stimulation (rTMS) as non-invasive brain stimulation method can elicit analgesic effects and has been shown to be beneficial in chronic pain conditions. In the literature, a variety of stimulation parameters and sites is reported, and results are heterogeneous.

**Methods:** In a cohort of cLBP patients seen in a neurosurgical clinic, we investigated the effectiveness of 13 sessions 20 Hz (2000 pulses) and 5 Hz (1800 pulses) rTMS stimulation over the left precentral gyrus (PCG) and left dorsolateral prefrontal cortex (DLPFC). The sham-group was limited to 7 sessions of placebo stimulation. Outcome parameters were acquired using the German Pain Questionnaire (GPQ), Depression, Anxiety and Stress Scale (DASS), and SF-12 questionnaire.

**Results:** 9 patients in the PCG group and 7 in the DLPFC group finished the protocol. In the latter, pain perception was significantly more reduced (38.17%) than in the PCG group (56.11%) ( $p = <0.001$ ). In comparison to the sham-group, quality of life increased in the DLPFC-group (40.47 vs. 35.06) ( $p = 0.016$ ).

**Discussion:** Left DLPFC rTMS can improve quality of life and reduce pain levels in cLBP patients, while PCG stimulation showed no significant reduction of pain. Non-invasive brain stimulation can be an alternative treatment for patients without indication for (further) surgery and exhausted conservative treatments.

## P 015

**Minimal-Invasive Pain Procedures are effective in different degenerative pain generators in CLBP – a prospective, observational cohort study**\*A. Veihelmann<sup>1</sup>, F. Beck<sup>1</sup>, U. Spetzger<sup>2</sup><sup>1</sup>Sportklinik Stuttgart, Dept. Wirbelsäule, Stuttgart, Deutschland<sup>2</sup>Klinikum Karlsruhe, Neurochirurgie, Karlsruhe, Deutschland

**Background:** Still the distinction between specific and non-specific back pain is difficult but enormously important, as it is known that patients with non-specific CLBP should rather be treated non-invasively. On the other hand, it is estimated that a significant number of spinal surgeries are performed in Germany, where – besides the economic problem – the patients do often not benefit. Our aim was to determine how effective it is that all CLBP patients with proven degenerative causes (specific low back pain) are treated with minimally invasive pain procedures.

**Methods:** 386 eligible patients with CLBP and/or sciatica resistant to conservative therapy were screened and 167 could be enrolled in this study, 17 were lost to follow-up. Indications for minimally invasive spine-interventions (MIS) in all remaining 150 individuals were made by an experienced spinal surgeon. Before and 6 months after the intervention numeric rating scale (NRS) and Oswestry disability index (ODI) were recorded. Several different, targeted MIS-procedures were performed depending on the underlying condition such as radiofrequency of the facet- and SI-joint, intradiscal electrothermal therapy in case of discogenic pain as well as epidural neuroplasty in patients with disc herniation and/or epidural fibrosis.

**Results:** 6 months after surgery, all patients revealed clinically important improvements in NRS and ODI. There was a statistically significant decrease in NRS ( $p < 0.05$ ), as well as significant increase in ODI ( $p < 0.001$ ) 6 months after the pain procedures. This was also true for the results of all the different pain generators and the subsequent performed above procedures alone.

**Conclusions:** In this group of CLBP / sciatica patients due to specific low back pain, all patients showed significant

improvement after suited treatment with MIS. Thus, the indication of MIS should be regularly proved prior the indication for open surgery in patients with CLBP due to degenerative changes in order to possibly prevent of open surgery and for prevention increasingly limited healthcare funds.

## P 016

**The determining factor in the conservative treatment of chronic low back pain remains the treatment of kinesiophobia**\*I. M. Norberg<sup>1</sup>, M. Norberg<sup>1,2</sup><sup>1</sup>Lavey Médical SA, Froideville, Schweiz<sup>2</sup>Institut Beauregard, Froideville, Schweiz

**Introduction:** In chronic low back pain, the most expensive patients are them with long-standing sick-leave of more than 6 months. Interdisciplinary rehabilitation models are successful. But which are the important factors for a positive evolution?

**Purpose/Aim:** The aim of this study was to analyze the different parts of an interdisciplinary rehabilitation program to determine the important factors for a positive response. The primary outcome was the evolution of the work capacity at 5 years, the secondary outcome was the evolution of the apprehension for movement and work.

**Materials and Methods:** We have done a retrospective analysis of 1030 of our patients 5 years after that they have followed a multidisciplinary rehabilitation program. The program contained physical training, game playing, occupational tasks developed on the basis of the fear-avoidance model of Waddell with psychological support.

We analyzed the work capacity evolution, the apprehension questionnaires (FABQ, Tampa scale (TSK), PCS Catastrophism questionnaire, the PACT (subjective work capacity) and the Oswestry questionnaire at beginning of the program and at follow-up at 1 and 5 years.

**Results:** The patients were divided in two groups according to rehabilitation program: We saw an increase in the global work capacity at 5 years all patients: passing from 41 to 67% and an increase to 80% ( $p < 0.01$ ) for the patients having followed a program more based on reassurance. This result was associated with a greater decrease in apprehension in this group with a decrease in fear-avoidance according to the Fabq, and the TSK. These patients had an approach centered on pain and work fear based on the Vlayen fear avoidance model.

**Discussion:** In chronic low back, a multidisciplinary rehabilitation program, gives a global work capacity of 80% in patients having an increase in self-confidence. This result is increased on focalising on patient's apprehensions with gradual exposure according to the fear-avoidance model developed by Waddell and explored by Vlayen. The correlation was confirmed and seen in the psychological part, with less apprehension and also with increased global SF 36 values.

An increase in body confidence rests the important factor in these functional restoration programs which should be implanted more world-wide.

## P 017

**Epidural patch with autologous platelet rich fibrin (PRF) for the treatment of persistent post-puncture headaches**\*I. Vasilikos<sup>1</sup>, K. Argiti<sup>1</sup>, N. Lützen<sup>2</sup>, A. Stathi<sup>1</sup>, L. M. Kraus<sup>1</sup>,C. Fung<sup>1</sup>, U. Hubbe<sup>1</sup>, J. Beck<sup>1</sup>, H. Urbach<sup>2</sup><sup>1</sup>Universitätsklinikum Freiburg, Klinik für Neurochirurgie, Freiburg i. Br., Deutschland<sup>2</sup>Universitätsklinikum Freiburg, Klinik für Neuroradiologie, Freiburg i. Br., Deutschland

**Introduction:** Post-dural puncture headache (PDPH) is a complication that affects up to 30% of the patients after lumbar puncture or myelography. Orthostatic or postural headache is the cardinal symptom and the epidural blood patch (EBP) is currently the standard of care. In up to 48% of patients treated with EBP, symptoms persist and one or more revision-EBPs are necessary. Treating this group of patients is challenging, as epidural scar-tissue formation after initial EBP complicates revision epidural treatments which aim to reach and cover the responsible dural-

defect. Platelet-rich fibrin (PRF) is an autologous biomaterial easily prepared from the patient's own blood, after a cycle of angulated centrifugation. Immediately after preparation, PRF is semi-liquid and has excellent rheological properties. After a targeted epidural injection, PRF starts to polymerize creating a fibrin-network covering the dural deficit.

Here we present our single-center experience with PRF-epidural patches (EPP) for the treatment of a series of patients with persistent PDPH.

**Material and Methods:** A series of 12 patients with PDPH (3 men and 9 women; mean age, 45 years) where one or more (range: 1-6) EBPs did not relieve their symptoms, were referred to our institution for treatment. PRF was prepared after blood was collected from each patient and was then percutaneously injected epidurally, under fluoroscopic guidance. The symptoms of the patients were collected perioperatively and a 6-week follow-up period.

**Results:** The EPP epidural injection with volumes ranging between 15-45ml were well tolerated across the cohort. The injection associated pain (unidimensional numeric rating score – NRS) of EPP was 58% less compared to their latest EBP injection ( $p \leq 0.05$ ). Headache impact test scores (HIT-6) before and 6-weeks after EPP revealed a statistically significant reduction in symptoms by a mean of 33.3% ( $p < 0.05$ ). No adverse effects were reported. PDPH-associated symptoms were statistically significantly relieved in all patients six weeks after the intervention.

**Discussion:** Epidural autologous platelet-rich fibrin patch (EPP) appears to be a safe alternative to alleviating persistent symptoms of PDPH and the pain associated with the procedure was significantly reduced compared to EBP.

#### P 018

##### Patient-controlled sublingual sufentanil tablet system vs. intravenous opioid analgesia for postoperative pain management after lumbar spinal fusion surgery

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**Purpose:** This retrospective cohort study investigated the efficacy of a sublingual sufentanil tablet system (SSTS) in comparison to intravenous patient-controlled analgesia (IV-PCA) with piritramid for the management of postoperative pain following lumbar spinal fusion surgery.

**Methods:** This was a retrospective analysis of patients undergoing single- or two-level lumbar spinal fusion surgery and receiving the SSTS or IV-PCA for postoperative pain relief as part of multimodal pain management that included IV paracetamol and oral metamizole. The following variables were collected: postoperative pain intensity and frequency scores using the numerical rating scale (NRS), hospital anxiety and depression scale (HADS), occurrence of nausea, postoperative mobilization, and patient satisfaction (MacNab criteria).

**Results:** Sixty-four patients were included. Those receiving the SSTS ( $n=30$ ) had significantly lower pain intensities on the operative day (NRS: 4.0, CI: 3.6–4.3 vs. 4.5, CI: 4.2–4.9;  $P < 0.05$ ) and one day postoperatively (NRS: 3.4, CI: 3.1–3.8 vs. 3.9 CI: 3.6–4.3;  $p < 0.05$ ) compared to patients receiving IV-PCA ( $n=34$ ). No differences were observed on postoperative days 2 to 5. SSTS patients experienced more nausea than IV-PCA patients ( $p=0.027$ ). Moreover, SSTS patients had a higher percentage of early mobilization following surgery than IV-PCA patients ( $p=0.040$ ). Regarding patient satisfaction, no significant differences were seen between the groups.

**Conclusion:** The SSTS is a potentially advantageous alternative to opioid IV-PCA for use within a multimodal approach to managing postoperative pain after lumbar fusion surgery. Furthermore, the potentially higher emetic effect of SSTS should be considered, and the patient should be able to perform the application.

#### P 019

##### Anterior thoracolumbar column reconstruction with the vertebral body stent- safety and efficacy

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**Introduction:** Percutaneous vertebral augmentation procedures – such as vertebroplasty, balloon-kyphoplasty and vertebral body stents- have emerged as valid anterior column reconstruction techniques for thoracolumbar compression fractures. They provide early mobilization, higher pain alleviation and long-term bone consolidation compared to conservative treatment options. In comparison to balloon kyphoplasty or vertebroplasty, vertebral body stenting (VBS) intends to combine fracture consolidation and permanent height restoration. The aim of this study was to assess safety and efficacy of vertebral body stenting by analyzing (1) radiographic outcome, (2) clinical outcome, and (3) perioperative complications in patients with traumatic, osteoporotic and metastatic vertebral compression fractures treated with VBS at minimum 6 months follow-up.

**Materials/Methods:** In this retrospective cohort study, 78 patients ( $61 \pm 14$  [21-90] years; 67% female), who have received a vertebral body stent due to a traumatic, osteoporotic or metastatic thoracolumbar compression fracture at our hospital between 2012-2020, were included (Figure 1). Median follow-up was 0.9 years with a minimum follow-up of 6 months. Radiographic and clinical outcome was analyzed directly, 6 weeks-, 12 weeks-, 6 months-postoperatively, and at last follow-up.

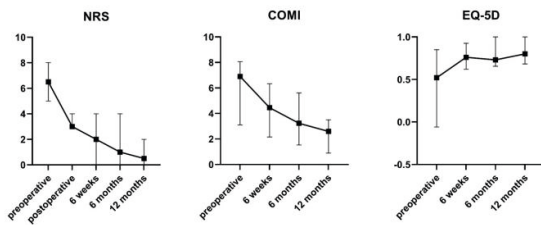
**Results:** Anterior vertebral body height of all patients improved significantly by mean  $6.2 \pm 4.8$ mm directly postoperatively ( $p < 0.0001$ ) and remained at  $4.3 \pm 5.1$ mm at last follow-up compared to preoperatively ( $p < 0.0001$ ). The fracture kyphosis angle of all patients improved significantly by mean  $5.8 \pm 6.9$  degrees directly postoperatively ( $p < 0.0001$ ) and remained at mean  $4.9 \pm 6.9$  degrees at last follow-up compared to preoperatively ( $p < 0.0001$ ). The segmental kyphosis angle of all patients improved significantly by mean  $7.1 \pm 7.6$  degrees directly postoperatively ( $p < 0.0001$ ) and remained at mean  $2.8 \pm 7.8$  degrees at last follow-up compared to preoperatively ( $p=0.03$ ). Back pain was ameliorated from a preoperative median Numeric Rating Scale value of 6.5 to 3.0 directly postoperatively and further bettered to 1.0 six months postoperatively ( $p=0.0001$ ) (Figure 2). Revision surgery was required in one patient (1.3%) after 0.4 years.

**Discussion:** Vertebral Body Stenting is a safe and effective treatment option for osteoporotic, traumatic and metastatic compression fractures.

Fig. 1



Fig. 2



## P 020

### Classifications and therapy recommendations for thoracolumbar spinal injuries – a comparison between AO Magerl, TLICS and AOSpine

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**Introduction:** In order to determine the efficiency or reliability of a new classification system, a direct comparison with existing classification systems should be performed. The aim of this Study is to compare the interobserver reliability of three international classification systems for thoracolumbar spine injuries (AO Magerl, Thoracolumbar Injury classification score ‘‘TLICS’’, Thoracolumbar AO Spine classification ‘‘TL AOSpine’’) and to determine the reliability of their treatment recommendations.

**Materials/Method:** This is a monocentric, prospective analysis of Radiological and clinical data of 100 patients with fractures of the thoracolumbar region. Only cases with traumatic fractures were included, pathological fractures were excluded. Five spine surgeons with different degrees of experience classified the available x-rays, CT and MRT images using the three classification systems AOSpine, AO Magerl and TLICS, and the associated treatment recommendation according to Thoracolumbar AO Spine classification injury score ‘‘TL AOS IS’’, the German society for trauma surgery ‘‘DGU’’ and TLICS. For the statistical evaluation, the interobserver reliability, according to Cohen’s kappa, was calculated.

**Results:** AO Magerl showed moderate interobserver reliability ( $\kappa = 0.46$ ) for morphological classification and substantial agreement ( $\kappa = 0.71$ ) for DGU treatment recommendations. TLICS showed fair interobserver reliability ( $\kappa = 0.35$ ) for morphological classification, substantial agreement ( $\kappa = 0.69$ ) for therapy recommendations according to TLICS. TL AOS showed substantial interobserver reliability ( $\kappa = 0.69$ ) for morphological classification and a substantial agreement ( $\kappa = 0.77$ ) for treatment recommendations (TL AOS IS).

**Discussion:** The TL AOS is a reliable classification, with superior interobserver reliability compared to AO Magerl and TLICS. The treatment recommendations of TL AOSIS have higher interobserver reliability compared to other treatment recommendations (DGU and TLICS).

## P 021

### Pseudarthroses after dens fractures – a predictive model for therapy selection with retrospective multi-center strategy

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The underlying aim of this study is to assess the impact of treatment (operative vs. conservative) on osseous union and to identify potential risk factors for odontoid fracture nonunion.

This study is based on a multi-center retrospective analysis of routinely collected data.

A total of 415 individuals who sustained odontoid fracture and were treated in either of four tertiary referral centers in --- blinded --- were included in the study.

The following variables were included in the analysis: age, gender, loss of reduction, mechanism of injury (high vs. low energy), fracture classification (Anderson II vs. III), presence of

comorbidities (Charlson comorbidity index), and treatment (conservative, anterior screw fixation with one or two screws, posterior C1/C2 spondylolysis, cervico-occipital fusion).

We included potential contributing factors for fracture nonunion in cross-validated extreme gradient boosted (XGBoost) and binary logistic regression models aiming to identify risk factors for nonunion. Performances of the different models were compared using the area under the receiver operating characteristic curve (AUROC).

In our cohort, 187 (45%) had radiologically confirmed dens nonunion six months post-injury. Rates of nonunion were significantly different between the treatment groups ( $p < 0.001$ ) with the highest rate in the conservatively treated group. No significant differences in nonunion rates were found between anterior screw fixation and conservative management ( $p > 0.05$ ). The factors age, fracture classification, conservative treatment, and cervico-occipital fusion showed the highest model contributions in the XGBoost.

Higher age, Anderson type II fractures, and conservative treatment are the main risk factors for odontoid nonunion. Anterior screw fixation did not differ significantly from conservative treatment in terms of fracture union of the odontoid.

## P 022

### Pediatric spine trauma – Results of the German national Childspine-multicenter study including 367 patients

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**Background:** In general, pediatric spinal injuries are rare. No reliable data on the epidemiology of spinal injuries in pediatric patients in Germany are available. Especially in pediatric patients, for whom the medical history, clinical examination and the performance of imaging diagnostics are difficult to obtain, all available information on a spinal injury must be taken into account.

**Objective:** The aim of this study was to provide epidemiological data for pediatric patients with spinal trauma in Germany in order to enhance future decision-making for the diagnostics and treatment of these patients.

**Material and methods:** Within the framework of a national multicenter study, data were retrospectively obtained from 6 German spine centers for 7 years between January 2010 and December 2016. In addition to the demographic data, the clinical databases were screened for specific trauma mechanisms, level of injury as well as accompanying injuries. Furthermore, diagnostic imaging and the treatment selected were also analyzed.

**Results:** A total of 367 children (female: male= 1:1.2) with a total of 610 spinal injuries were included in this study. The mean age was 12 years ( $\pm 3.5$  years). The most frequent trauma mechanisms were falls from  $< 3$  m and traffic accidents. The imaging diagnostics were only rarely carried out with the child under anesthesia. Younger children (0–9 years old) suffered more injuries to the cervical spine, whereas injuries to the thoracic and lumbar spine were more frequently found in older children ( $> 10$  years old). The children frequently showed accompanying injuries to the head and the extremities. Accompanying spinal injuries mostly occurred

in adjacent regions and only rarely in other regions. Around 75% of the children were treated conservatively.

**Conclusion:** The results were different from the knowledge obtained from adult patients with spinal trauma and describe the special circumstances for pediatric patients with spinal trauma. Despite certain limitations these facts may help to enhance future decision-making for the diagnostics and treatment of these patients.

#### P 023

##### Reproducibility and dynamic course of A3 and A4 fractures – a biomechanical analysis

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**Introduction:** To induce reproducible life-like vertebral body fractures in human cadaveric specimens is desirable to understand fracture morphology and surgical training of reduction techniques using spinal instrumentation as well as any kyphoplasty. The aim of the present study was to develop a technique that allows reproducible and reliable simulation of compressive burst fractures (A3 and A4) of a single vertebral body in a complete spinal segment and to observe the fracturing process.

**Materials and Methods:** Six cadaveric lumbar segments were fractured using a custom-made drop-test bench (4 complete lumbar spine segments (L1-5) one divided into (Th12-L2) and (L3-5)). The upper and lower endplates were embedded and the spinal segments were positioned at 15° of kyphosis. Axial impact was induced by free-fall. Pre-fracture CT scans were performed to measure the bone density (HU). Post-fracture x-rays and CT scans were performed to define the exact fracture configurations and classification. The general AO Spine classification for thoraco-lumbar burst fractures was applied. High-speed imaging was used to monitor steps of fracture process of three specimens.

**Results:** In all six lumbar vertebral segments life-like burst fractures (A3 and A4) were achieved (4 L3 fractures, 1 L1 and 1 L4). Three A3 and three A4 fractures were observed. All fractures were reliably reproducible when applying the same simulation parameters. High-speed imaging of the fracture simulation revealed identical steps of fracture mechanism. Initially, fracturing of the front edge was observed with the upper fragment blowing out circularly around the vertebral body and overhanging the lower fragment. Then, further axial compression depressed both endplates primarily from the ventral part. Following this compression, the trailing edge of the vertebral body was broken. CT scans showed characteristics of complete burst fractures including both edges.

**Conclusion:** Using a custom-made test bench, we were able to induce reproducible lumbar burst fractures of a single vertebral body in a complete spinal segment. Following this reproducible simulation, the fracturing process can be characterised in details as well as the specimens can be available for surgical training.

#### P 024

##### Evaluation of the OF-score and therapeutic recommendations for osteoporotic thoracolumbar fractures (EOFTT) – monocentric results of a multicenter prospective trial

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**Introduction:** The aim of the multicenter study (EOFTT) was to evaluate the recently developed OF-score and treatment recommendations for osteoporotic thoracolumbar fractures.

**Material and Methods:** Monocentric evaluation of a multicenter prospective cohort study. All inpatients with osteoporotic

thoracolumbar fractures with a follow-up between 6 weeks and 12 months were included and evaluated clinically and radiologically. Treatment was based on the recommendations of the OF-score which considers radiological and clinical patient data and suggests treatment (6 points surgery).

**Results:** Over a period of 28 months 60 (69%) of 87 treated inpatients fulfilled the inclusion criteria. 82% were female. T-score was  $4.04 \text{ g/cm}^2 \pm 0.73$ , average age  $76 \pm 8.1$  years and 25% had more than one fracture. Classification according to OF was: OF 1: none, OF 2: 25% OF 3: 23% OF 4: 45% OF 5: 7%. Three patients (5%) suffered from a fracture related neurological deficit. The median OF-score (25% / 75% quartile) was 7 (5/9). 37 patients (62%) were treated according to the score recommendations including 2 (3%) conservative treatments, 30 (50%) surgical treatments, and 5 (8%) relative indications for surgery. 17 patients (28%) were treated surgically despite a conservative recommendation and 6 patients (10%) vice versa. Subsequently, after discharge 3 conservative treated patients (5%) needed surgery. Overall, 90% of all patients were treated operatively of whom 28 (55%) received kyphoplasty, 11 (22%) stabilization with pedicle screws, and 12 (24%) a combination of both. The overall complication rate was 24% including one surgical revision due to a hematoma. 9 (15%) patients developed adjacent fractures. The average follow-up time was  $32 \pm 19$  weeks (range 6-72). The clinical parameter improved significantly ( $p < 0,001$ ) from preop to last follow-up (preoperative, day of discharge, final follow-up, mean  $\pm$  standard deviation): VAS back  $8.2 \pm 2.1$ ;  $4.4 \pm 2.3$ ;  $3.1 \pm 2.7$ . ODI:  $71\% \pm 16\%$ ;  $61\% \pm 12\%$ ;  $36\% \pm 19\%$ . Barthel-scale:  $72 \pm 23$ ;  $80 \pm 14$ ;  $91 \pm 13$ . The MCD of ODI was only reached by the group of score-concordant patients. The local bisegmental kyphotic angle (GDW) showed no significant improvement over time ( $p = 0,802$ ) (preoperative, day of discharge, final follow-up, mean  $\pm$  standard deviation):  $-3^\circ \pm 21^\circ$ ;  $-0^\circ \pm 19^\circ$ ;  $-3^\circ \pm 20^\circ$  (all kyphosis). There was no significant difference ( $p = 0,600$ ) in mobility before fracture and at the point of follow. Also, there was a significant improvement ( $p < 0,001$ ) of antiosteoporotic therapy from preop (57%) to last follow-up (95%).

**Conclusion:** The recommendations according to the OF-Score, whether surgical or non-surgical, lead to clinical favorable results after 8 months on average. Regarding the MCD of ODI there was a better outcome in the group of score-concordant therapy.

Fig. 1

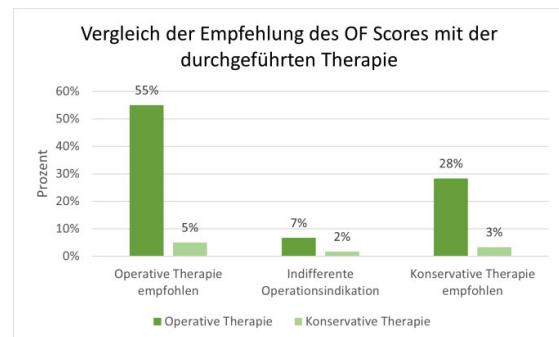
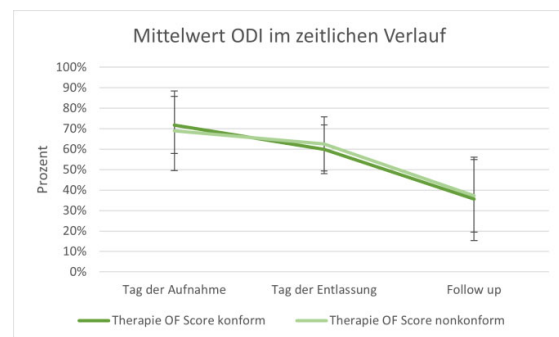


Fig. 2





**P 025**

**Percutaneous reduction of thoracolumbar fractures using monoaxial screws – comparison of two instruments based on initial reduction and loss of reduction**

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**Introduction:** The minimally invasive surgical treatment of thoracolumbar vertebral body fractures is of great importance in spinal surgery today. It offers many advantages compared to the open surgical care. In this study, two percutaneous systems (Aesculap and DePuy) with there reduction tools were assessed with regard to initial reduction outcome. In addition, the loss of reduction in relation to a two-stage ventral stabilization was examined using a subsample.

**Material/Method:** In a monocentric study, data from patients with a fracture of the thoracolumbar junction (Th11-L2) were retrospectively examined. All patients got percutaneous surgery with monoaxial screws. Using CT and X-ray images, sagittal bisegmental Cobb angles (CA) were measured pre- and postoperatively. In addition, the fracture classification according to AOSpine, the bone quality using Hounsfield Units (HU) and complications were recorded. The influence of both systems was checked using ANOVA with repeated measures. The impact of HU and fracture morphology on the reposition results was examined using Pearson- and Spearman-correlation.

**Results:** A total of 117 patients (Aesculap: N=31, DePuy: N=86, 74 men, 43 women, age: 49±15 years, bone quality: 153±46 HU) were included in the study. There was a relevant repositioning effect of 9° on average (p<0.001), independent of the used system (p=0,374). The distribution of the CA can be seen in table 1. The better the bone quality, the better the initial reduction (p<0.001). In a subsample of 53 patients, the ventrally stabilized patients (N=31) had less loss of reduction than the non-ventrally stabilized patients (N=22) over a 7-month period. But the difference was not significant (p=0.057). Bone quality also showed a positive effect here: the better the bone quality, the less loss of reduction (p=0.024). The average cut-suture time was 58±18 minutes. The average length of hospital stay was 12±16 days. Complications only occurred in DePuy patients (5 of 86).

**Discussion:** Since Aesculap and DePuy do not differ in terms of reduction, both systems, despite technical differences, can be used to reduce thoracolumbar fractures in a comparable manner. The influence of the HU on the reduction should be considered in the surgical therapy. With regard to ventral stabilization, further studies with a larger number of patients are necessary. Innic loosening was only seen in DePuy. This might be sample-caused or could be related to the technique of rod pushing.

Table 1: Bisegmental Cobb angles (CA) at T1 (preoperative) and T3 (directly postoperative) divided according to the used system

**Fig. 1**

	System	Mittelwert (°)	Standardabweichung (°)	Anzahl
°GDW in T1	Aesculap	-10	11	31
	DePuy	-9	9	86
	Gesamt	-9	9	117
°GDW in T3	Aesculap	0	9	31
	DePuy	0	8	86
	Gesamt	0	8	117

**Fig. 2**

	System	Mean (°)	standard deviation (°)	number
CA in T1	Aesculap	-10	11	31
	DePuy	-9	9	86
	Total	-9	9	117
CA in T3	Aesculap	0	9	31
	DePuy	0	8	86
	Total	0	8	117

**P 026**

**Severity of osteoporotic fractures in relation to hounsfield units of computed tomography in 550 vertebral bodies**

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**Introduction:** Osteoporotic fractures of the spine manifest clinically by nonspecific back pain. The DGOU developed a classification for osteoporotic vertebral fractures and a score for therapeutic indication (OF classification and OF score). The aim of the study is to investigate the relationship of hounsfield units from a CT of the thoracic or lumbar spine and the extent of the fracture. Furthermore, we investigated the treatment of fractures depending on the OF classification and the hounsfield units.

**Methods:** The study is a monocentric study with a retrospective data analysis. We examined 550 vertebral bodies of patients who underwent CT of the thoracolumbar transition as well as the lumbar spine due to back pain between 01/01/2015 and 02/15/2019. Inclusion criterion was a diagnosis of osteoporotic vertebral body fracture. Collected data were entered into the IBM SPSS statistical program for Windows (version 23; SPSS, Inc., Chicago, IL, USA) for analysis. We collected age, sex distribution, and the mean values of the hounsfield units (MHU) of each vertebral body in the thoracic and lumbar spine. Furthermore, we classified the fractures using the established OF classification. Furthermore, we documented the treatment.

**Results:** Patients were 72.5 years old on average (min. 49; max. 92). Of these, 46.0% were vertebral bodies from male patients and 54.0% from female patients. The most common osteoporotic fractures were type II (36.7%) and type III fractures (37.6%) according to the OF classification, followed by type IV (17.5%), V (5.3%) and I (3%). A linear relationship between the MHU and the severity of the fracture was not demonstrated (Fig.1). OF I and II fractures were predominantly treated conservatively (Fig. 2). In contrast, OF type III fractures were operated on in 86%, with an internal fixator in 63% of cases (MHU: 81); or kyphoplasty in 37% of cases (MHU: 65). The MHU values of the conservative group were 74.6. In the type IV fracture group, 79% were treated surgically and 21% conservatively. The MHU in the conservative group was 47.5 and in the operative group 72.5. 65.5% of the type V fractures were treated with an internal fixator and 34.5% were treated conservatively.

**Discussion:** The severity of an osteoporotic fracture is independent of the HU in the CT of the adjacent vertebral bodies. The study shows that the HU are not the decisive criterion for the severity of the osteoporotic fracture and thus for the OF classification, but that the corresponding trauma must be considered as a possible cause.

Fig. 1: Bar chart showing MHU as a function of fracture type according to OF classification

**Fig. 1**

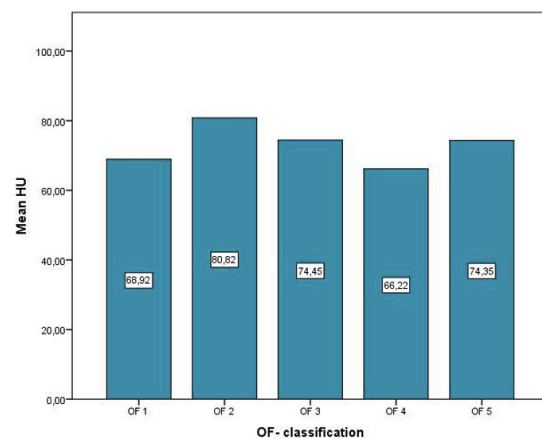
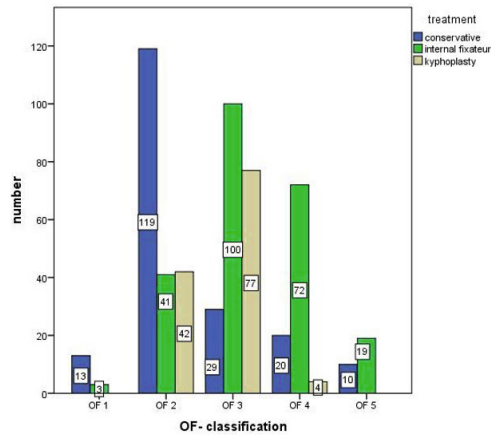


Fig. 2: Bar chart showing the frequency distribution of the different treatments in the respective OF classification groups

Fig. 2



#### P 027

##### Incomplete burst fractures at the thoracolumbar junction – clinical and radiological outcome after monosegmental fusion with special titanium cage

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**Purpose:** Incomplete burst fractures at the thoracolumbar junction are surgically corrected due to the high risk of kyphosis. The restoration of a balanced spinal profile significantly improves the health-related quality of life (HRQOL) of affected patients. The most biomechanically stable treatment strategy is the posterior-anterior correction and stabilization. The present study analyzes the clinical and radiological results after monosegmental fusion of thoracolumbar incomplete burst fractures with a special titanium cage whose bearing surface and height were selected according to the anatomical conditions.

**Methods:** This prospective study analyzed the clinical and radiological outcome of patients with thoracolumbar incomplete burst fractures treated from December 2019 to January 2022. Inclusion criteria were thoracolumbar A3 fractures (AO Spine) with a McCormack of at least 6 points. Patients <18 and >65 years of age as well as patients with multiple trauma were excluded. After dorsal correction and stabilization with a polyaxial screw-rod system, an anterior monosegmental fusion was performed by a mini-open thoracotomy with autologous cancellous bone and a titanium cage individually selected to match the vertebral body width with a correspondingly wide bearing surface and height. Clinical and radiological outcome were assessed preoperatively, after 3 and 12 months, as well as after posterior implant removal by a thoracolumbar X-ray in upright position and a PROM questionnaire using the ODI, EQ-5D-5L and PROMIS-29.

**Results:** Twenty-two patients (mean age  $48 \pm 14$  years) were included. The mean McCormack was  $7 \pm 1$  points. In almost 75% of the cases, Th12 (18.2%) and L1 (54.5%) were fractured. Bony fusion was seen in 100% of the cases. The average monosegmental kyphotic angulation was  $15.2^\circ \pm 6.1^\circ$  preoperatively. After posterior-anterior stabilization and fusion monosegmental kyphosis angulation was  $5.9^\circ \pm 6.2^\circ$ . This corresponds to an average correction of  $9.3^\circ \pm 6.3^\circ$ . Postoperatively, there was no significant loss of correction even after dorsal material removal. ODI, EQ-5D-5L and PROMIS-29 showed a significant improvement in HRQOL during follow-up.

**Conclusion:** The modern titanium cage used in this study is a suitable and safe implant for monosegmental fusion of thoracolumbar incomplete burst fractures. The wide bearing surface of the cage on the cortical edges of the fractured vertebra optimally prevents a secondary loss of correction. The risk of

pseudarthrosis appears to be minimal with a fusion rate of 100%. The HRQOL can be significantly improved by the very good correction results with the used implant.

#### P 028

##### Correlation between spinal fusion length and functional rehabilitation success of patients with traumatic cervical spinal cord injury

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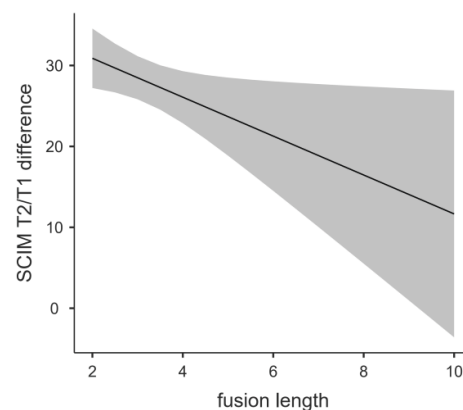
**Introduction:** Surgical stabilization has been established as the therapeutic gold standard of cervical spine injuries. This is especially true for injuries involving neurologic deficits. It is naturally to assume, that especially in those suffering from tetraplegia, remaining agility of the cervical spine is of special interest. While in 2006, 63% of ventral interbody fusions, the most prevalent approach in cervical injuries, were monosegmental, in 2020 only 56% of patients received the same length of fusion. Paraplegiologists are demanding an approach along the lines of "as short as possible, as long as necessary". Evidence regarding the effects on functional success does not exist so far. This study aims to determine if there is a correlation between fusion length and rehabilitation success.

**Materials/Methods:** A total of 199 patients between 18 and 50 years old, who were treated in a German spinal cord injury center between 2003 and 2018, were subject to analysis. The rehabilitation progress was represented by the Spinal Cord Independence measure (II) and analyzed via multiple linear regression. This multifactorial approach included age at injury, level of injury, time until admission to the spinal cord injury center and ASIA Impairment Scale (AIS) values at admission.

**Results:** Within the multiple linear regression of the Spinal Cord Independence Measure (SCIM) difference between admission and release, it could be shown, that for those with cervical spinal cord injuries, a significant negative correlation of about -2.4 points per added fusion segment and therefore between fusion length and functional outcome exists, while also considering several potential confounders (Figure 1). Aside from fusion length, initial evaluation via AIS and initial evaluation of SCIM values could be identified as significant predictors of rehabilitation success.

**Discussion:** This study included a large collective and is able to show, that under consideration of several cofactors like the neurological status and the initial functionality of patients at admission, a negative correlation between vertebral fusion length and rehabilitation success exists. The study design does not allow for final conclusions regarding causality, but the results should lead to a more critical approach to surgical fusions and be included in the spinal surgeons' considerations.

Fig. 1



## P 029

**Fusion Assessment in Standalone Lateral Lumbar Interbody Fusion – 3D-printed Titanium versus Polyetheretherketone (PEEK) cages**

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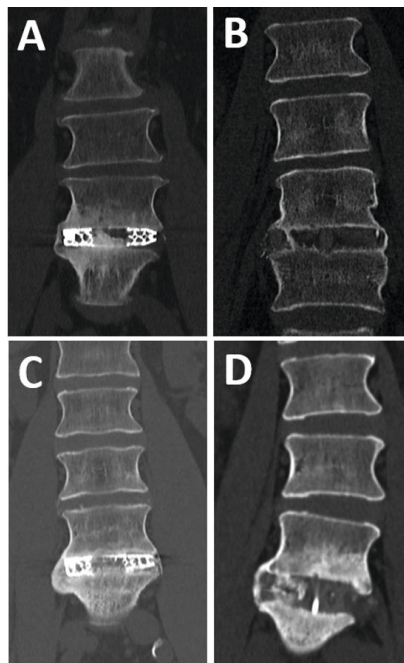
**Objective:** Compare fusion at two independent timepoints (early and late) between 3D-printed Titanium (Ti) and Polyetheretherketone (PEEK) cages in patients undergoing standalone lateral lumbar interbody fusion (SA-LLIF). We hypothesized that 3D-printed Ti cages show higher fusion rates at an early timepoint compared to PEEK.

**Methods:** A retrospective study of patients undergoing SA-LLIF with 3D-printed Ti cages and PEEK cages between 11/2016 and 01/2020 at a single academic institution was done. Fusion was assessed for each treated level using multiplanar reconstructed computed tomography (CT) scans. Presence of fully bridged interbody trabecular bone or continuous bone centered in the cage was considered as fusion.

**Results:** In total, 91 patients (136 levels) were included in the final analysis, 49 patients (72 levels) in the early group and 42 patients (64 levels) in the late group. CT scans were performed on average 8.2±1.8 months postoperatively for the early group and 18.9±7.7 months for the late group. In the early group, fusion was significantly higher for 3D-printed Ti cages compared to PEEK cages (95.8% versus 62.5%;  $p=0.002$ ), whereas in the late group no significant difference was seen (94.7% versus 80.0%;  $p=0.756$ ).

**Conclusions:** In SA-LLIF, porous 3D-printed Ti cages showed significantly higher fusion rates at an early timepoint compared to PEEK. However, the difference in fusion rates between 3D-printed Ti cages and PEEK cages was found not to be significantly different at a later timepoint in another patient group. This might support the assumption that 3D-printed Ti cages with a porous architecture are more osteoconductive compared to PEEK and tend to fuse earlier.

**Fig. 1**



## P 030

**Comparison of anterior lumbosacral interbody fusion in the right lateral decubitus position (xALIF) with conventional ALIF technique**

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**Objective:** Conventional minimally invasive anterior lumbosacral interbody fusion (ALIF) in the supine position can be challenging in obese patients due to peritoneal fat tissue masses. Recently, ALIF in lateral decubitus position (xALIF) was introduced, using passive gravitational forces to retract the peritoneal sac, offering potential benefits in this patient population. We aimed to evaluate this procedure's feasibility and safety and to report our initial clinical experience with xALIF surgery compared to conventional ALIF surgery.

**Methods:** In this prospective observational study, all patients with degenerative lumbar spine disease who underwent monosegmental xALIF surgery in the right decubitus position or conventional ALIF surgery in the supine position at the L5/S1 level between 03/2020 and 06/2022 were analyzed. Pre- and postoperative standing radiographs of the spine were compared by Surgimap® software. Bilateral pedicle screw instrumentation was applied in all patients

**Results:** We included 13 xALIF cases and 8 conventional ALIF cases. xALIF was feasible in all cases, and no change in the planned surgical approach was required. Mean body mass index did not differ between the two groups (27.1 ± 7.1 in the xALIF vs 27.8 ± 6.4 in the ALIF group;  $p = 0.829$ ).

The xALIF and conventional ALIF groups did not differ in terms of correction of segmental sagittal alignment, mean postoperative NRS scores (xALIF 2.5 ± 2.0 vs ALIF 2.9 ± 1.0;  $p = 0.55$ ), duration of surgery (155 ± 9 min for xALIF vs 123 ± 13 min for conventional ALIF;  $p = 0.21$ ), and duration of hospital stay (7.1 ± 5.6 days in the xALIF vs 11.4 ± 7.7 [VN1] [ML2] days in the conventional ALIF group;  $p = 0.104$ ). There were no differences in intraoperative adverse events and postoperative complications between the two groups ( $p = 0.846$ ).

**Conclusion:** Our results indicate that xALIF is feasible and noninferior to conventional ALIF surgery. The xALIF may be particularly useful in ventral lumbosacral fusion surgery in obese patients. [ML2]Bei drei Patienten sehr lange Aufenthalte, daher der lange durchschn. Aufenthalt

## P 031

**Predictors of clinically important improvement at 2-years post minimally invasive lumbar interbody fusion for degenerative lumbar disease**

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**Objective:** Minimally invasive lumbar interbody fusion (MI-LIF) as a treatment for degenerative lumbar disease (DLD) is often

associated with substantial improvements in disability, back-pain (BP), leg-pain (LP), and quality of life (QoL). However, it is difficult for surgeons to determine which patients are most likely to benefit from MI-LIF.

The objectives of these exploratory analyses were to: i.) examine which patient and surgery variables predicted clinically important improvement (MCID) in disability, pain and QoL; and ii.) establish how predictive characteristics vary depending on choice of outcome measure.

**Materials/Methods:** DLD patients (N=340) indicated for anterolateral (ALIF, DLIF, OLIF) or posterior (MIDLF, PLIF, TLIF) MI-LIF surgery were consecutively enrolled across 26 sites in a prospective 5-year global cohort study (NCT02617563). Each procedure was performed by an experienced surgeon who determined the approach for each patient. Demographic and outcome data [ODI, VAS BP and VAS LP, and EQ-5D index score] were collected at baseline, 4 weeks, 3-months and 1- and 2-years post-surgery.

To determine which patients achieved an MCID, a threshold of at least 30% reduction from baseline ODI score at 2-years follow-up was used as criterium. Stepwise selection from logistic regression was used to identify the prognostic characteristics for the response to treatment. A significance level of 0.10 was required to allow a candidate variable into and remain in the model. Candidate predictors included demographic and disease related variables, patient reported outcome scores at baseline, number of levels treated, and surgical approach. Variables were considered significant as predictors with significance  $p \leq .05$ . This analytical procedure was repeated using BP, LP and EQ-5D index as dependent variables to establish the reliability of predictors of MCID.

**Results:** Patients' baseline ODI score was the only statistically significant predictor of achieving clinically important reductions in disability at 2-years follow-up ( $p=.0006$ ). If ODI at baseline increased by 1 or 10 point(s), the odds to achieve a reduction of at least 30% from baseline at 2-years follow-up increased by 3.4% or 39.4% respectively, while holding other variables constant. When LBP was used as a dependent variable, LBP at baseline ( $p<.0001$ ) and posterior surgical approach ( $p=.0494$ ) were predictors of MCID. Leg-pain score at baseline ( $p<.0001$ ), the EQ5D VAS score at baseline ( $p=.0165$ ), and not having any prior lumbar surgery ( $p=.0156$ ) were predictors of MCID for alleviation of LP. The EQ-5D index score at baseline was the only predictor of MCID for QoL ( $p < .0001$ ).

**Conclusion:** Disease severity at baseline appears to be a reliable indicator of the likelihood of MCID at 2-years post MI-LIF. Some variation in predictor variables does however exist between outcome measures. It remains to be confirmed whether these predictor variables remain significant at 5-year follow-up.

#### P 032

##### Surgical treatment of intra / extraforaminal lumbar disc herniations – a safe and simple lateral pars interarticularis approach

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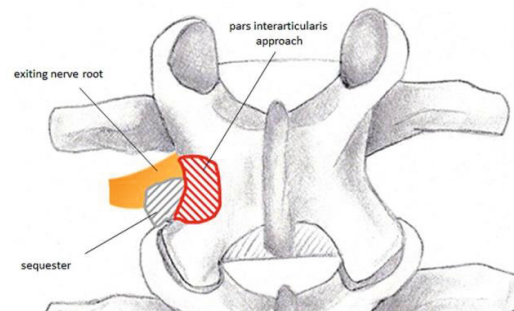
**Introduction:** Although intra/extraforaminal disc herniations make up only a minor portion of discectomies, the surgical procedures involved are often challenging due to impaired anatomical orientation and higher risk of spinal instability from facet joint disruption. To tackle these issues a lateral pars interarticularis approach has been described: After subperiosteal dissection the lateral aspect of the lamina is removed in the inferior region of pars interarticularis and cranial to the facet joint. Following resection of the ligamentum flavum below, the exiting nerve root and the ganglion are exposed and the sequester can be mobilized and extracted. In the largest series published yet, we report our experience using this approach for removal of lumbar intra/extraforaminal disc herniations and nerve root decompression.

**Methods:** The medical records of 167 patients undergoing surgery using this approach from 2014-2021 were assessed. Patient and pathology characteristics and clinical course including frequency of reoperations and long-term Oswestry-Disability-Index (ODI) and quality-of-life (QOL SF-36) were analyzed.

**Results:** Mean age was 61.5 years with a predominance of the male sex (59% : 41%). Main locations of herniations were the levels L3/4 (30.5%), L4/5 (52.7%) and L5/S1 (7.2%); 10.6% of all indications were foraminal stenoses or synovial cysts. Over-all, the median MRC grade at the last follow-up was 5/5 (range 4/5–5/5), which had improved by 1 grade compared with the preoperative grade (median of 4/5, range 2/5–5/5). The improvement of motor function between the latest follow-up examination and the preoperative status reached significance ( $p < 0.001$ ). 9/167 (6.6%) patients had to be reoperated at the same level due to a rest or recurrent disk prolapse, the most lately after a mean period of 19.3 ± 19 months. Seven patients (4.2%) had to be stabilized at the same level after 25.5 ± 26.1 months (mean), 4/7 patients had suffered from preoperative spondylolisthesis grade I. Long-term evaluation was available in 135 patients (80.3%) with a mean follow-up of 46.4 months. The ODI score at the final follow-up was 11 ± 13 (0-100; 0-20: minimal disability). According to the SF-36, the mean physical health composite score in the long-term questionnaire evaluation was 47.7 ± 9.6 and the mean mental health composite score was 53.8 ± 9.0, indicating a physical and mental health in the average population range (50 ± 10.0).

**Discussion:** Our observations suggest that the lateral pars interarticularis approach is safe and effective in the surgical management of intra/extraforaminal lumbar disc herniations. Due to its relative simplicity und good anatomical orientation, it offers the chance of a steep surgical [A1] learning curve, short operation times, and a satisfying neurological and QOL outcome during long-term follow-up.

Fig. 1



#### P 033

##### Healthcare resource use and patient-reported outcomes following minimally invasive fusion surgery for degenerative lumbar disease – a 2-year analysis

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**Objective:** Minimally invasive lumbar interbody fusion (MI LIF) has demonstrated improved patient-reported outcomes (PROs) 1-year post-surgery in degenerative lumbar disease (DLD) patients. Longer term data would provide valuable insights on the changes in healthcare use (HCU) and the course of improved PROs.

These interim exploratory analyses describe the healthcare resource use for DLD patients and evaluate changes in PROs 2-years post MI LIF in the context of an ongoing 5-year international multicentre, prospective, observational cohort study (NCT02617563).

**Materials/Methods:** DLD patients (n=340) indicated for one- or two-level MI LIF were consecutively enrolled at 26 sites across Europe, Latin America, and Asia. Patients were operated via an anterolateral or posterior approach per surgeons' choice.

HCU data included conservative care (type and duration), length of hospital stay (LOS), time to first ambulation (TTFA), medication use, rehabilitation, paid sick leave, and reoperation rate. PROs were assessed at baseline and follow-up visits and included disability (ODI), back and leg pain (VAS) and quality of life (QoL; EQ-5D index score). Here, baseline and 2-year follow-up data are reported.

Paired sample t-tests and McNemar tests ( $\alpha = .05$ ) were used for change from baseline calculations.

**Results:** Mean subject age was  $58.7 \pm 10.8$  years, mean BMI  $27.2 \pm 4.7$  with the majority (60.9%) being female. Prior to surgery, patients had conservative care for  $23.3 \pm 26.5$  months including pain medication (90.9%), physical therapy (74.6%), spinal injections/nerve blocks (48.0%) and/or bracing (16.6%). Mean LOS was 7.1 ( $\pm 5.6$ ) days and TTFA 1.8 ( $\pm 1.5$ ) days. Following discharge 31.5% of patients (106/336) received rehabilitation services. Patients had unscheduled consultations in outpatient centers (40/336, 11.9%; mean  $3.2 \pm 4.7$  visits) and primary care (88/336, 26.2%; mean  $4.9 \pm 5.5$  visits); 24 patients (7.1%) had additional lumbar surgery.

The data reveals significant reductions in overall medication use ( $p < 0.001$ ) including opioid ( $p < 0.001$ ) and non-opioid analgesics ( $p < 0.001$ ) vs. baseline. Both the proportion of patients unable to work due to back- or leg-pain and those receiving paid sick leave decreased ( $p < 0.001$ ).

At 2-year follow-up, statistically significant improvements in disability, back-pain, leg-pain, and QoL were observed (all  $p < 0.001$ ; Table 1).

**Conclusion:** DLD has a substantial impact on QoL and HCU. These results demonstrate the mid-term success of MI LIF in improving patient outcomes and reducing healthcare burden. LOS and TTFA were slightly longer than reported in earlier studies. These differences might be attributable to regional differences in healthcare practices.

Fig. 1

Table 1. Healthcare resource use and outcomes of patients with degenerative lumbar disease.

Variable	Timepoint		P value	
	Baseline	2 Years follow-up		
Medication use in the past week (%)	269/340 (79.1%)	147/307 (47.9%)	<0.001	
Medication use by type (%)	Opioid Analgesics use, % (35.0%)	40/307 (13.0%)	<0.001	
	Non-Opioid Analgesics use, % (65.0%)	104/307 (33.9%)	<0.001	
	Other medications (35.3%)	75/307 (24.4%)	<0.001	
Work status	Not employed & unable to work due to back and/or leg pain, % (19.6%)	16/210 (7.6%)	<0.001	
	Employed but on sick leave, % (46.0%)	9/97 (9.3%)	<0.001	
	Paid sick leave (full or part time), % (43.7%)	8/97 (8.2%)	<0.001	
	Disability (ODI)	46.7 $\pm$ 11.7 (N=339)	17.6 $\pm$ 16.7 (N=296)	<0.001
Patient reported outcomes	Back-pain (VAS)	6.1 $\pm$ 2.6 (N=339)	2.5 $\pm$ 2.5 (N=297)	<0.001
	Leg-pain (VAS)	6.3 $\pm$ 2.6 (N=338)	1.6 $\pm$ 2.5 (N=297)	<0.001
	Quality of life (EQ-5D index)	0.519 $\pm$ 0.228 (N=334)	0.829 $\pm$ 0.177 (N=296)	<0.001

P 034

**Prediction of the mono- and bisegmental sagittal endplate angle (m/bEPA) by angulation of adjacent levels in the thoracolumbar spine in supine position**

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**Introduction:** The interindividual differences in the sagittal profile of the spine are receiving considerable attention in the surgical treatment of thoracolumbar spine trauma. The aim of surgical interventions is to restore the sagittal profile to prevent post-traumatic kyphotic deformity. How the individual pre-morbid sagittal profile can be estimated on a once fractured segmental level has not been adequately described yet. Hence, the aim of this study is to analyse the correlation between the respective mono- and bisegmental endplate angle (m/bEPA) and the mean m/bEPA of the cranial and caudally adjacent m/bEPA. Furthermore, we aim to identify whether the position of a spine segment can be predicted using the m/bEPA.

**Material/Methods:** A monocentric retrospective analysis of sagittal spine CT scans in supine position was used to measure the sagittal m/bEPA. Only CT-Scans of patients without pelvic – and spine deformities or fractures were analysed.

The predicted m- and bEPA was calculated as the corresponding mean EPA of the cranial and caudal adjacent segment.

Pearson correlation coefficient was used to examine the correlation between the measured m/bEPA and predicted m/bEPA. SPSS was used for statistical analysis and significance was defined as p-value of <0.05.

**Results:** A total of 287 patients (208 male, 79 female) with a mean age of 42 (18-87) years were included in this study. Positive correlation between the measured and predicted m/bEPA were observed ( $p < 0.001$ , Table 1). Regarding the mEPA a moderate correlation, which varies throughout the thoracolumbar spine (segment L2/3  $r = 0.760$ ; Th10/11  $r = 0.587$ ), could be observed. However, the bisegmental prediction showed a lower correlation (L2  $r = 0.345$ ; Th 11  $r = 0.284$ ).

**Conclusion:** The observed results indicate that mean m/bEPA correlate with the measured m/bEPA. Considering the prediction of the position of a spine segment using the mean m/bEPA of the adjacent m/bEPA, the prediction of mEPA seems to be more reliable than the bEPA. Nevertheless, the explained variance for mEPA was only moderate and therefore cannot be used as a single parameter to precisely predict the EPA in practice. In order to optimize the postoperative outcome regarding kyphotic deformity, further studies should be carried out to develop an algorithm for predicting the pre-morbid sagittal profile of the spine.

Table 1: Comparison of the measured and predicted mono- and bisegmental EPA. Data are given as mean and [min – max] in degree. Results of the Person correlation are given as  $r$ ,  $r^2$  and their p-value

Fig. 1

Table 1

		measured		predicted		Pearson correlation		
		Mean±SD	(min-max)	Mean±SD	(min-max)	r	r <sup>2</sup>	p
Monosegmental	Th9/Th10	-3°±4*	(-18°- 8°)	-4°±3*	(-17°-3°)	0.668	0.446	<0.001
	Th10/11	-4°±4*	(-17°- 7°)	-4°±3*	(-12°-3°)	0.587	0.345	<0.001
	Th11/Th12	-5°±4*	(-17°- 6°)	-4°±3*	(-13°-3°)	0.617	0.381	<0.001
	Th12/L1	-4°±5*	(-16°-12°)	-3°±4*	(-14°-8°)	0.720	0.518	<0.001
	L1/2	-1°±5*	(-16°-13°)	0°±4*	(-9°-12°)	0.727	0.529	<0.001
	L2/3	5°±5*	(8°- 21°)	5°±4*	(-6°-19°)	0.760	0.578	<0.001
Bisegmental	Th9	-6°±5*	(-31°- 6°)	-9°±4*	(-20°-1°)	0.446	0.199	<0.001
	Th10	-6°±5*	(-21°- 7°)	-8°±3*	(-19°-1°)	0.420	0.176	<0.001
	Th11	-7°±5*	(-23°- 6°)	-4°±3*	(-12°-6°)	0.284	0.081	<0.001
	Th12	-6°±6*	(-21°-11°)	-1°±3*	(-8°-10°)	0.383	0.147	<0.001
	L1	-2°±6*	(-16°-18°)	4°±4*	(-6°-19°)	0.495	0.245	<0.001
	L2	5°±7*	(-10°-27°)	12°±5*	(-2°-26°)	0.587	0.345	<0.001

## P 035

**Clinical and economical aspects of one- and two-stage thoracolumbar and lumbar 360-degree spinal fusion**\*M. Kube<sup>1</sup>, C. Bourgeois<sup>1</sup>, T. Pitzen<sup>1</sup><sup>1</sup>Marienhausklinikum St. Elisabeth Saarlouis, Orthopädie, Unfallchirurgie und Wirbelsäulenchirurgie, Saarlouis, Deutschland

**Introduction:** Thoracolumbar and lumbar 360-degree spinal fusion are among the most frequently performed procedures in spine surgery. They may be done as one- or two-staged procedure. The aim of this study is to compare the two procedures with respect to clinical and economical aspects.

**Material, Methods:** We identified patients that underwent one- or two-staged 360° spinal fusion surgery in our institution from 01.01.2015 to 31.12.2021, based on OPS-code. All cases were addressed via XLIF-approach and posterior percutaneous fusion. The following parameters were identified: sex, age, BMI, ASA-Score, diagnosis, time of surgery, time of anesthesia, ICU treatment (yes/no), bloodloss, blood transfusion, postoperative inhouse stay, complications and DRG-Income (effective weight x baserate). The data was collected in a retrospective cohort study by the electrical medial records of patients and integrated into SPSS. Statistics was carried out using SPSS, Mann-Whitney-U-Test, t-test, Chi-Quadrat-Test. Significance assumed for  $p < 0.05$ . The study was approved by the local ethic committee.

**Results:** 157 patients, 89 one-staged, 68 two-staged surgery. Sex ( $p = 0.727$ ), age ( $p = 0.373$ ), BMI ( $p = 0.534$ ), ASA ( $p = 0.965$ ), diagnosis ( $p = 0.507$ ), ICU treatment ( $p = 0.166$ ), blood transfusion ( $p = 0.846$ ), blood loss ( $p = 0.237$ ) and complication rates ( $p = 0.863$ ) were not significantly different between the groups. Patients following two-staged procedures were significantly longer in hospital ( $p 0.001$ ) and had a longer time of anesthesia ( $p 0.012$ ). However the generated income, which could only be evaluated for the year 2019, was significantly higher when surgery was performed in two-stages ( $p 0.001$ ).

**Discussion:** Thoracolumbar and lumbar 360° spinal fusion should be operated on the same day because data suggests no significant benefits of the two-staged procedure. The two-staged procedure shows longer inhouse stay after surgery and longer time of anesthesia. However, from an economical point of view a two-staged surgery may generate more income. The study illuminates the current dilemma of clinical necessity versus economic aspects.

## P 036

**Influence of anterior lumbar intersomatic fusion on sagittal balance**\*J. Löchel<sup>1</sup>, R. K. Zahn<sup>1</sup>, K. Labbus<sup>1</sup>, M. Putzier<sup>1</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Centrum für Muskuloskeletale Chirurgie (CMSC), Berlin, Deutschland

**Introduction:** The sagittal balance of the spine influences the surgical treatment and correction of adult spinal deformities. An advantage of the anterior lumbar interbody fusion (ALIF) procedure can be seen in the potential of correction of the deformity. To date, there is no published research investigating the immediate influence of an ALIF L5/S1 on the correction of the sagittal balance with a consistent multilevel surgical approach in the treatment of adult spinal deformities.

**Material and Methods:** To investigate the influence of the ALIF L5/S1 on the correction of the sagittal balance, we conducted a retrospective clinical study. 139 patients with adult spinal deformity undergoing multilevel spondylodesis with posterior lumbar interbody fusion were included. The lowest instrumented vertebra was S1 in all cases. Thereof, 66 patients had an additional ALIF L5/S1 during a ventro-dorsal procedure (ALIF group). The segmental lordosis L5/S1, the lumbar lordosis (LL) and the sagittal vertical axis (SVA) were analyzed pre- and postoperatively on standing total spine x-rays using the SurgiMap Spine software (Nemaris Inc., New York, NY, USA).

**Results:** There was no significant difference between both groups for the preoperative segmental lordosis L5/S1 (16.6° (PLIF) vs. 18.6° (ALIF);  $p=0.26$ ), LL (35.2° (PLIF) vs. 37.8° (ALIF);  $p=0.27$ ) and SVA (73mm (PLIF) vs. 68.6mm (ALIF);  $p=0.87$ ). The segmental lordosis L5/S1 of the PLIF group showed no significant

postoperative difference and was increased in the ALIF group (20.5°);  $p=0.004$ . The postoperative LL was increased in both groups (35.7° (PLIF) vs. 39.3 (ALIF);  $p=0.045$ ). The postoperative SVA showed no significant change, the SVA in the ALIF group was decreased (67mm);  $p=0.034$ .

**Discussion:** This is the first study investigating the influence of the ALIF in a consistent surgical treatment for patients with adult spinal deformities. We were able to show that the correction of the segmental lordosis L5/S1, the LL and the SVA is better to achieve.

## P 037

**Relevance of trigonometric method to achieve the correction angle for pedicular subtraction osteotomy in lumbar spine**\*M. Rivollier<sup>1</sup>, C. Barrey<sup>1</sup><sup>1</sup>Hospices Civils de Lyon, Bron, Frankreich

**Introduction:** PSO (Pedicule Subtraction Osteotomy) is the only way to effectively correct large rigid spinal deformities. The main advantage is that correction can be achieved in a single operation. In addition to the technique of performing the osteotomy, one of the difficulties is to achieve the pre-operative angular correction objective. Automated methods based on artificial intelligence are being developed, but they are still being evaluated and require substantial technical resources. This study proposes a simple, reproducible, relevant method based on trigonometric concepts and reliable intraoperative anatomical landmarks.

**Material and method:** This study is an observational, analytical, retrospective study carried out in a spine and spinal cord surgery department. It was carried out on patients with a rigid spinal deformity. This paper focuses on grade 3 and grade 4 osteotomies performed between 2013 and 2021. The idea of this study is to describe the accuracy of the trigonometric method used during the surgeries, inspired by trigonometric concepts used in tibial osteotomies in orthopaedics. To do this, we first measured the angle of correction achieved surgically at the PSO vertebra on the postoperative CT scan. Secondly, we calculated the theoretical angle of correction as a function of the height of the resected vertebral wall using the mathematical formula and the pre-operative CT scan. The difference in these two angles gives the delta angle.

**Results:** The study included 55 patients of whom 34 were women and 21 men. The average age at the time of surgery was 66 years. 75% of PSO were performed on L4. Degenerative pathology was the main indication (45%). The average angular delta was 1.4°. The minimum delta is 0.01°. The maximum delta is 5.64°. The standard deviation is 1.47. The average of the correction achieved at the level of the vertebra that underwent PSO is 22.8°. The average of the theoretical correction expected with the mathematical formula is 21.9°. The ODI score significantly improved by 6 points between pre- and post-op at 1 year. Similarly, with the VAS which is significantly improved by 5 points.

**Conclusion:** The mathematical method appears to be sufficiently accurate and reliable to be used in pre-operative planning to define the vertebral bone resection required for the desired local correction. A prospective study is needed to validate this technique.

Fig. 1

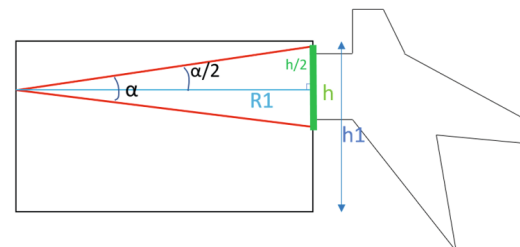
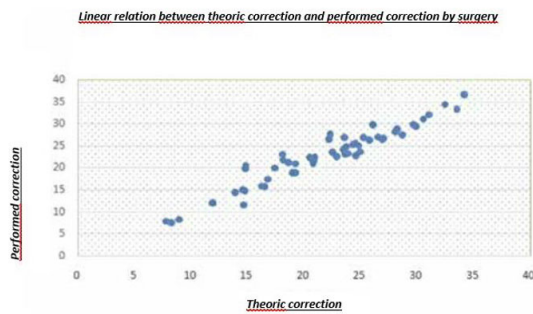


Fig. 2



## P 038

**The effect of obesity on paraspinal muscle morphology in patients undergoing lumbar fusion surgery**

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**Introduction:** Obese patients who undergo spine surgery have a higher risk of developing postoperative complications, although functional outcomes after lumbar fusion are not inferior when compared to non-obese patients. This study aimed to investigate the effect of obesity on the psoas and lumbar spine extensor muscle morphology in patients undergoing lumbar spinal fusion, with a particular emphasis on sex-related differences.

**Material and Methods:** Patients undergoing lumbar fusion surgery between 2014–2017 at a single academic institution who had a preoperative lumbar magnet resonance imaging (MRI) scan performed within 6 months before surgery were retrospectively included. Muscle measurements were conducted of the psoas and posterior paraspinal muscles (PPM; *erector spinae* and *multifidus*) at the superior endplate of vertebral bodies L3–L5 using manual segmentation and an automated pixel intensity threshold method. Outcome parameters included the functional cross-sectional area (FCSA) and the percentage of fat infiltration (FI). Kendall's correlation coefficient ( $\tau_b$ ) was calculated to assess crude relationships among variables. Multivariable linear regression analyses with adjustments for age and race were conducted to investigate the influence of obesity on outcome parameters. All analyses were stratified by biological sex. Statistical significance was defined as  $p < 0.05$ .

**Results:** 114 patients (60.5% female, 92.1% Caucasian, median age 68.8 years, body mass index (BMI) 28.2 kg/m<sup>2</sup>) were included in the final analysis. The prevalence of obesity was 46.7% in men and 36.2% in women ( $p = 0.330$ ). For both sexes, age showed a significant negative correlation with the FCSA of PPM at L3–L5 and a significant positive correlation with the FI of PPM at L3–L5. In men, BMI showed a significant positive correlation with the FCSA of psoas at L3 and L5, and with the FCSA of PPM at L3. In women, BMI showed a significant positive correlation with the FCSA of psoas and PPM at L3 and L4. In the multivariable analysis, obesity was positively associated with the FCSA of the PPM at L3 in men ( $\beta = 5.941$ ; 95% CI 0.375 – 11.507;  $p = 0.037$ ).

In women, obesity was negatively associated with the FCSA of the PPM at L3 ( $\beta = -0.006$ ; 95% CI -0.011 – -0.001;  $p = 0.012$ ), and positively associated with the FCSA of the PPM at L4 ( $\beta = 1.253$ ; 95% CI 1.138 – 1.380;  $p < 0.001$ ) and L5 ( $\beta = 1.186$  95% CI 1.013 – 1.388;  $p = 0.034$ ). For both sexes, neither were the muscle parameters of the psoas, nor the FI of PPM affected by obesity in the adjusted analysis.

**Discussion:** This study demonstrated that obesity significantly affects the FCSA but not the FI of PPM in men and women who undergo lumbar fusion surgery, irrespective of age and race. Further studies are needed to investigate whether these findings of increased paraspinal lean muscle mass are protective against mechanical complications after lumbar fusion surgery.

## P 039

**Vascular supply and neurological outcome after surgical treatment of spinal intradural hemangioblastoma – a multicenter retrospective case series**

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**Introduction:** Spinal cord hemangioblastoma are rare highly hypervascularized benign neoplasms. Surgical resection remains the treatment of choice, with a significant risk of postoperative neurological deterioration.

**Material/Methods:** We performed a retrospective multicenter study including five high-volume neurosurgical centers including patients surgically treated for spinal hemangioblastoma between 2006 and 2021. Clinical status, surgical data, preoperative angiograms, and embolization were assessed when available. Follow-up records were analyzed, and logistic regression performed to assess possible risk factors for neurological deterioration.

**Results:** We included 60 patients in 5 high-volume neurosurgical centers in Germany and Austria. Preoperative angiography was performed in 30% of the cases, ten patients underwent preoperative embolization. The clinical outcome revealed a transient postoperative neurological deterioration in 38.3%, depending on symptom duration and preoperative McCormick grading, but patients recovered in most cases until follow-up. Posterior tumor location and presence of a syrinx favored gross total tumor resection. Preoperative embolization was not associated with postoperative worsening.

**Diskussion:** Spinal hemangioblastoma patients significantly benefit from early surgical treatment with only transient postoperative deterioration and complete recovery until follow-up. The performance of preoperative angiograms remains subject to center disparities.

## P 040

**Surgery in acute metastatic spinal cord compression – timing and functional outcome**

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**Background:** Patients with acute spinal cord injury (SCI) due to compression by spinal metastases (SM) may experience long-term functional impairment. It has been established that surgical decompression improves neurological outcomes, but the effect of early surgery remains uncertain. Our objective was to evaluate the impact of early versus late decompressive surgery with or without instrumentation for acute SCI due to SM. Earlier, we presented

preliminary data; we hereby report final analyses after study conclusion.

**Methods:** We retrospectively reviewed a consecutive cohort of all patients undergoing surgery for SMs at our institution. We determined the prevalence of acute MSCC; the time between acute neuro-logical deterioration as well as between admission and surgery (standard procedure: decom-pression and instrumentation); and neurological impairment graded by the ASIA scale upon presentation and discharge.

**Results:** 693 patients with surgery for spinal metastasis were screened. 140 patients (21.7%) had acute MSCC, defined as neurological impairment corresponding to ASIA grade D or lower acquired within up to 72 hours before admission. Non-MSCC patients had surgery for SM-related cauda equina syndrome, radiculopathy and/or spinal instability. Most common locations of the SM in acute MSCC were the thoracic (77.9%) and cervical (10.7%) spine. Per standard of care, acute MSCC patients underwent surgery including decom-pression and instrumentation, and the median time from admission to surgery was 16±14 hours (interquartile range 10 – 22 hours). Within the group of patients with acute MSCC, those who underwent early surgery (i.e., before the median 16 hours) had a significantly higher rate of ASIA improvement by at least one grade at discharge (26.5%) compared to those who had late surgery after 16 hours (10.1%;  $p = .024$ ). Except for a significantly higher sepsis rate in the late surgery group, complication rates did not differ between the late and early surgery subgroups.

**Conclusion:** We report data on the largest cohort of patients with MSCC to date. Early surgery is pivotal in acute MSCC, substantially increasing the chance for neurological improvement without increasing complication rates. We found no significant impact when surgery was performed later than 24 hours after admission. These findings will provide the framework for a much-needed prospective study. Until then, the treatment strategy should entail the earliest possible surgical intervention.

#### P 041

##### Minimally invasive facetectomy and fusion for resection of dumbbell tumors in the lumbar spine

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**Background:** Resection of dumbbell tumors can be challenging, and facet joint sparing approaches carry the risk of incomplete resection. In contrast, additional facetectomy may allow better surgical exposure at the cost of spinal stability. Aim of this study is to compare facet-sparing and facetectomy approaches for treatment of lumbar spine dumbbell tumors.

**Methods:** In a cohort study setting, we analyzed all patients with lumbar spinal dumbbell tumors operated on in a single academic center between 2014 and 2021. Only Eden type 2 and 3 lesions were included into the study. Conventional facet-sparing microsurgical or facetectomy approaches with minimal invasive fusions were performed according to individual surgeons' preference. Primary outcome was extent of resection. Secondary outcomes were tumor progression over time and perioperative adverse events.

**Results:** Nineteen patients were included. Nine patients were operated on using a facet-sparing technique. Ten patients underwent facetectomy and fusion. While only one patient (11%) in the facet-sparing group experienced gross total resection (GTR), this was achieved for all patients in the facetectomy group (100%). The relative risk (RR) for incomplete resection in the facet-sparing cohort was 18.7 (95% CI 1.23 – 284.047;  $p=0.035$ ). In addition, time to progression was shorter in the facet-sparing cohort ( $p=0.022$ ) and all patients with residual tumor underwent a second resection after a median follow-up time of 42 months (IQR 25–66). Except for one case of transient monoparesis of the leg in the facet-sparing cohort, we did not find any relevant perioperative adverse events in both groups.

**Conclusion:** Minimal invasive resection of lumbar Eden type 2 and 3 dumbbell tumors including facetectomy in combination with

instrumentation appears to be safe and superior to the facet-sparing approach in terms of local tumor control.

Fig. 1

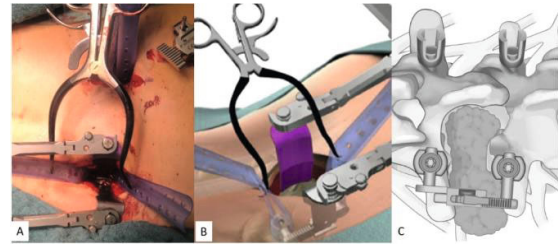
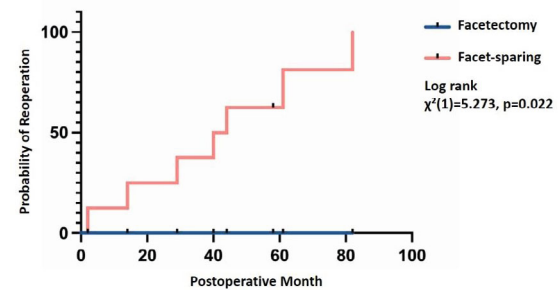


Fig. 2



#### P 042

##### Qualitative assessment of titanium vs. carbon-fiber/PEEK pedicle screw-related artifacts – a cadaveric study

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**Introduction:** Dorsal instrumentation and decompression are the mainstays of spinal tumor treatment. Replacing titanium screws with carbon fiber–reinforced PEEK (CFRP) screws can reduce the imaging artifacts on neural structures and perturbations of radiation dose. Further reduction of metal content in such screws might enhance the benefit. The aim of this study was to assess the artifacts produced by all-titanium (Ti-Ti), CFRP thread–titanium head (C-Ti) and all-CFRP (C-C) screws.

**Methods:** A cadaveric spine was used to place Ti-Ti, C-Ti and C-C pedicle screws consecutively from Th2 to S1. CT and 1.5 and 3 Tesla MRI were performed for each screw system. Axial T1 and T2 scans of representative thoracic and lumbar regions were assessed for artifacts. The artifacts were classified as not relevant, considerable or severe.

**Results:** We evaluated 92 screws and made 178 artifact assessments in total. The artifacts were clearly visible in CT scans but did not influence the visualization of intraspinal structures. Severe MRI artifacts were found in 28% (17/60, mostly in the thoracic spine) of the Ti-Ti, 2% (1/60, all T1) of the C-Ti and 0% of the C-C screws, and considerable artifacts were found in 47% (28/60) of Ti-Ti, 10% (6/60, only one T2) of C-Ti and 0% of the C-C screws,  $p<0.001$ .

**Conclusions:** CFRP pedicle screws reduced the artifact intensity in spinal structures, as compared to titanium screws, and may be beneficial for planning radiotherapy and for follow-up imaging. All-CFRP screws demonstrated an enhanced effect on dorsal structures.



**P 043****Postoperative cerebrospinal fluid leakage following surgery of intradural pathology – a retrospective single center analysis**S. Krahwinkel<sup>1</sup>, M. Gallus<sup>1</sup>, B. Al Barim<sup>1</sup>, W. Stummer<sup>1</sup>, \*M. Schwake<sup>1</sup><sup>1</sup>Universitätsklinikum Münster, Klinik für Neurochirurgie, Münster, Deutschland

**Introduction:** Postoperative cerebrospinal fluid leakage (CSFL) is a feared complication after spinal surgery of intradural pathologies and may cause prolonged hospital stay (LOS), impaired wound healing and subsequently higher treatment costs. So far, data concerning risk factors of CSFL is lacking, and is urgently required in order to find new strategies to prevent and manage the occurrence of CSFL.

**Methods:** We performed a retrospective analysis of all patients that had an intradural pathology and underwent surgery at our department between 2013 and 2021. The primary endpoint was the incidence of clinically proven CSFL. Suspected risk factors such as patients' characteristics, neurological status, surgical approach, location of the pathology, histopathology, and postoperative bed rest were analyzed.

**Results:** We found 434 patients (female 225 (51,8%), male 209 (48,2%) in our data base, with mean age of 48 years (range: 3-93). Six patients (1.4 %) had a postoperative CSFL. In all these cases patients had an intradural tumor (100%), five of them (83%) had it in the upper half of the spine (above D-6), in three cases (50 %) CSFL appeared after secondary surgery, and three patients (50%) had a laminectomy. Additionally, in four cases (66.7%) a duraplasty with a patch was performed for closure, which was implemented due to large defects of the dura caused by tumor infiltration. In three cases (50%) CSFL was developed despite postoperative bed rest and two (33%) had a CSFL in combination with surgical site infection. Finally, five patients (5/6, 83 %) underwent revision surgery, in the other cases it was treated with a lumbar drain.

**Conclusion:** In our study, we could not identify any modifiable risk factors that can prevent a postoperative CSFL. Nevertheless, our data indicate that patients with recurrent tumor, infiltration of the dura and laminectomy seem to be more susceptible to develop such complication.

**P 044****Relevance of nerve root sacrifice for spinal foraminal and/or dumbbell schwannomas**\*G. Capo<sup>1</sup>, A. Vandenbulcke<sup>1</sup>, G. D'Onofrio<sup>1</sup>, C. Barrey<sup>1</sup><sup>1</sup>Hopital Neurologique Lyon, HCL, Spinal departement, Lyon, Frankreich

**Objective:** To achieve total resection in surgical treatment of spinal schwannoma, avoiding thus the risk of recurrence, involved root resection is usually needed. In contrast to pure intradural lumbar schwannoma, root sacrifice for intra-foraminal and/or dumbbell schwannoma is controversy regarding the risk for motor function. The aim of the study is to confirm the safety and benefits of nerve root section in the treatment of intra-foraminal/dumbbell spinal schwannoma.

**Methods:** All spinal schwannomas with foraminal extension who underwent surgical resection from 2014 to 2021 in our institution were collected. Tumor size, scalloping of vertebral body and enlargement of the intervertebral foramen on MRI were measured. Preoperative and postoperative clinical findings (neurological status) were also collected. Operative complications and long-term outcome were analyzed.

**Results:** A series of 23 patients were included in the study. Between these, 8 (34%) were dumbbell-shaped schwannomas. 6 cases (26 %) were located in the cervical spine, 4 (17 %) in the thoracic spine, and 13 (57 %) in the lumbosacral spine. The most common preoperative symptom was the pain (16 pts, 69%). 7 patients (30%) presented sensory disturbance and 9 (39%) had motor weakness (MRC 4/5). 2 patients presented urinary bladder dysfunction. Pyramidal signs were observed in 1 patient.

The involved nerve root was cut in all cases. Complete resection was achieved in 20/23 patients. No recurrence was observed in patients with complete resection.

Two patients, which presented dumbbell schwannomas with extensions into myofascial structures, complained of immediate new postoperative motor deficit. One of them recovered quickly within 3 months. The other patient had severe paresis of the dorsiflexion of the foot persistent at 3 months, and partial recovery at one year follow up (MRC 4-/5).

Post-operative radicular sensory disturbances described were: hypoesthesia in 6 patients (26%) and dysesthesia and hyperesthesia in 2 patients (8%). In all these cases the sensory deficits were non disabling.

Neuropathic pain was reported in 3 cases (13%): 1 patient needed medical treatment; 1 patient showed refractory neuropathic pain with lack of response to medical treatment. In the latter case a spinal cord neurostimulator was implanted.

**Conclusion:** In the patients examined in our study, sacrifice of the foraminal root (both ventral and dorsal components) permitted to achieve total tumor resection, complying the oncologic rules and reducing the risk of tumor recurrence. Also, based on collected data, the incidence of nerve dysfunction is very low and acceptable, and when it occurs, good recovery at follow up has been observed.

**P 045****Effect of reduced preoperative performance status on surgical outcome for metastatic spinal disease**\*M. Lenschow<sup>1</sup>, M. Lenz<sup>2</sup>, N. von Spreckelsen<sup>1</sup>, J. Ossmann<sup>1</sup>, J. Meyer<sup>2</sup>, J. Keßling<sup>2</sup>, L. Nadjiri<sup>3</sup>, S. Telentschak<sup>1</sup>, K. Zarghooni<sup>2</sup>, P. Knöll<sup>2</sup>, M. Perrech<sup>1</sup>, E. Celik<sup>3</sup>, P. Eysel<sup>2</sup>, R. Goldbrunner<sup>1</sup>, M. J. Scheyerer<sup>2</sup>, V. Neuschmelting<sup>1</sup><sup>1</sup>Universitätsklinikum Köln, Zentrum für Neurochirurgie, Köln, Deutschland<sup>2</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>3</sup>Universitätsklinikum Köln, Klinik und Poliklinik für Radioonkologie, Cyberknife- und Strahlentherapie, Köln, Deutschland

**Objective:** Decompressive surgery for metastatic spine disease is an important component of multimodal treatment to preserve or restore ambulatory function, but must be traded against the risk of surgery-related morbidity, perioperative complications and potential events of delay in adjuvant treatment. Therefore, the aim of this study was to investigate the impact of reduced preoperative performance status on neurologic outcome and for surgery related risk assessment.

**Methods:** In this retrospective analysis we screened 738 patients who underwent surgical treatment for spinal metastasis at our spine center between 2012 and 2022.

Preoperative functional status was determined using the Karnofski Performance Scale (KPS). Patients were divided into a "reduced" (KPS 30 to 60 %) and "good" (KPS 70 to 100 %) performance group and compared with respect to neurological outcome, classified according to the Frankel grading system, and perioperative complications.

**Results:** A total of 466 patients (63.1%) were included. The median follow-up time was 8 ( $\pm$  13.5) months. Surgical decompression with or without instrumentation was performed in 93.1% of all patients, 6.9% were treated with instrumentation alone.

Preoperative performance status was reduced (KPS 30 to 60) in 60.5% of all patients.

Perioperative complications occurred in 35.4% of all cases, the most common being wound-related (12.2%), cardiovascular (10.3%) or nonsurgical infections (8.8%). The overall incidence of complications did not differ significantly between patients with 'reduced' (36.9%) or 'good' (33.2%) performance status ( $p = 0.429$ ). Perioperative mortality was 1.7%, all deceased patients demonstrated a "reduced" performance status prior to surgery.

Following surgical decompression, improvements in Frankel score were not significantly different in patients with "good" (33.3%) or "reduced" (39.9%) performance status ( $p = 0.935$ ). Subgroup

analysis of functional outcomes showed that preservation or restoration of walking ability (Frankel grades D and E) after surgical decompression was significantly more frequent in patients with "good" performance status (98.9% vs. 89.2% in patients with reduced performance status;  $p = 0.000$ ).

**Conclusion:** Our results suggest overall favorable outcomes following surgical treatment of spinal epidural metastases, although functional outcome may be related to preoperative performance status. Considering the high burden of perioperative complications associated with surgical treatment of spinal epidural metastases, the indication for surgery must be made with caution.

#### P 046

##### Stabilization surgery for instable tumorous lesions of the cervicothoracic junction is associated with a high complication profile

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**Introduction:** Tumorous lesions causing instability of the cervicothoracic junction of the spine require complex surgical strategies due to the anatomy and the high biomechanical load of this part of the spine. Aim of this retrospective monocentric study was to evaluate and quantify the complication rate after stabilizing surgical treatment of the cervicothoracic junction for neoplastic diseases.

**Methods:** Records of all consecutive patients receiving surgical treatment for tumorous lesions of the spinal levels C7 – T2 between 2010 – 2020 were evaluated. Relevant epidemiological, clinical and surgical data were assessed. Spinal Instability Neoplastic Score (SINS) was calculated on the basis of preoperative imaging. Complications were grouped in general and implant associated complications.

**Results:** Records of a total of 26 patients were analyzed. Mean age of the 17 male and 9 female patients was 60 years. 23 patients were treated for metastases, 2 for plasmacytoma and 1 for Giant-cell-tumor of the bone. Mean preoperative Karnofsky Performance Score was 60 %. Mean preoperative SINS was 14. Instability of the spine was the main indication for surgical therapy in 24 patients (92 %). Of 18 patients (69 %) with preoperative neurological deficits surgical therapy lead to partial improvement in 8 (44 %) and complete neurological improvement in 4 (22 %) cases. In 14 (54 %) cases surgery-related complications occurred. General complications occurred in 10 cases (38 %): Wound healing disorders in 8 cases (30 %), postoperative hematomas needing surgical evacuation in 2 cases (7.7 %). Implant associated complications occurred in 6 cases (23 %): Malposition of implants in 3 cases (11.5 %), hardware failure in 3 cases (11.5 %). In-hospital mortality rate was 11.5 %.

**Conclusion:** Both general as well as implant associated complication rates were high. In combination with a high in-hospital mortality rate our data underline the high demands required when considering surgical therapy of tumorous lesions of the cervicothoracic spine.

#### P 047

##### Evaluating a cutting-edge augmented reality-supported navigation system for spinal instrumentation

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**Objective:** Dorsal instrumentation using pedicle screws is a standard treatment for multiple spinal pathologies such as trauma, infection, or degenerative indications. Intraoperative three-dimensional (3D) imaging and navigated pedicle screw placement is used at multiple centers. For the present study we evaluated a new navigation system enabling augmented reality (AR)-supported pedicle screw placement while integrating navigation cameras into the reference array and drill guide. The aim of the present study was to evaluate its clinical application regarding safety, efficacy, and accuracy.

**Methods:** A total of 20 patients were operated on between 06/2021 and 01/2022 using the new technique for intraoperative navigation. Intraoperative data with focus on accuracy and patient safety including patient outcome were analyzed. The accuracy of pedicle screw placement was evaluated by intraoperative CT imaging.

**Results:** A median of 8 (4-18) pedicle screws were placed in each case. Percutaneous instrumentation was performed in 14 patients (70%). The duration of pedicle screw placement (duration scan – scan) was 56 +/- 26 (30-107) minutes. Intraoperative screw revision was necessary in 2 of 180 pedicle screws (1.1%). Intraoperatively, no major complications occurred – one case of delay due to software issues and one case of difficult screw placement were reported.

**Conclusion:** The use of the present AR-supported system for navigated pedicle screw placement for dorsal instrumentation in clinical routine could be confirmed by the present study's results. It provides a reliable and safe tool for 3D imaging-based pedicle screw placement, only requires a minimal intraoperative setup, and provides new opportunities by integrating AR.

#### P 048

##### Reducing the patient radiation dose during CT-guided periradicular infiltration therapy – less radiation exposure with the same efficiency

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**Objectives:** This retrospective cohort study investigated the radiation exposure and clinical efficiency of a new institutional low-dose protocol for computed tomography (CT)-guided lumbar periradicular infiltration (PRI).

**Methods:** This was a retrospective matched-pair comparison of patients undergoing single-level lumbar PRI therapy employing a new low-dose CT protocol consisting of a helical scan with reduced energy levels and tube current vs. the institutional standard CT protocol. The following variables were collected: dose-length product (DLP) for the planning step, interventional step, and total examination, number of CT guidance scans, examination time, and postprocedural improvement on the numerical rating scale for radicular pain (NRS).

**Results:** Forty-five patients were allocated to each group. A sufficient radiation dose reduction of 30% during PRI was achieved with the low-dose protocol with a median DLP of 9.8 mGy\*cm compared to 32.9 mGy\*cm with the standard protocol ( $P < 0.001$ ). No need for additional multiple scans during the interventional mode was observed in the low-dose group, resulting in a comparable procedure time between the groups. Furthermore, the short-term pain-reducing effect of PRI was comparable between the low-dose and standard protocols (median deltaNRS=4 in both groups).

**Conclusions:** Our low-dose protocol with less tube voltage and lower electric current leads to less radiation exposure with the same safety and efficiency. In conclusion, every facility that performs CT-based procedures should check whether a further dose reduction is applicable to avoid stochastic radiation damage to the patient.

#### P 049

##### Changes in paraspinal muscle morphology after standalone lateral lumbar interbody fusion – a quantitative MRI-based analysis

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**Introduction:** Standalone lateral lumbar interbody fusion (SA-LLIF) without posterior instrumentation can be an alternative to 360° fusion in selected cases. The absence of instrumentation and corresponding metal artifacts on magnetic resonance imaging (MRI) scans allows a quantitative assessment of the spinal musculature. This study aimed to investigate quantitative changes in paraspinal muscle morphology that occur on index levels after SA-LLIF.

**Material and Methods:** Patients undergoing SA-LLIF between 2008–2021 at a single academic institution who had both preoperative and postoperative lumbar MRI, performed between 3–18 months after surgery for any reason were retrospectively included. Muscle measurements were conducted of the psoas and posterior paraspinal muscles (PPM; *erector spinae* and *multifidus*) on index levels using manual segmentation and an automated pixel intensity threshold method. Changes in the total cross-sectional area (TCSA), the functional cross-sectional area (FCSA), and the percentage of fat infiltration (FI) were assessed. The paired *t*-test or the Wilcoxon signed-rank test were used for the pairwise comparison of continuous variables according to their distribution. Spearman's correlation coefficient ( $\rho$ ) was calculated to assess crude relationships among variables. Statistical significance was defined as  $p < 0.05$ .

**Results:** 67 patients (55.2% female, age  $64.3 \pm 10.6$  years, BMI  $26.9 \pm 5.0$  kg/m<sup>2</sup>) with 125 operated levels were included in the final analysis. Follow-up MRI scans were performed after  $8.7 \pm 4.6$  months, mostly for low back pain. Psoas muscle parameters did not change significantly over time, and there was no significant difference between left- and right-sided trans-psoas approaches. Among PPM, the mean  $\pm$  SD TCSA at L4/5 significantly increased over time, from  $4445.8 \pm 932.0$  mm<sup>2</sup> to  $4608.7 \pm 884.9$  mm<sup>2</sup> ( $+4.8 \pm 12.4\%$ ;  $p = 0.013$ ). Furthermore, mean FI of PPM significantly increased over time both at L3/4 and L4/5, from 45.6% to 48.7% ( $+3.1 \pm 6.5\%$ ;  $p = 0.002$ ), and from 51.5% to 54.5% ( $+3.0 \pm 7.0\%$ ;  $p = 0.002$ ), respectively. Changes in FI of PPM at L3/4 showed a significant negative correlation with BMI ( $\rho = -0.333$ ;  $p = 0.024$ ), whereas changes in FI of PPM at L4/5 showed a significant negative correlation with the time interval between surgery and follow-up MRI ( $\rho = -0.313$ ;  $p = 0.017$ ). In multilevel procedures including  $\geq 2$  spinal levels, only changes in FI of PPM significantly correlated among spinal levels ( $\rho = 0.442$ ;  $p = 0.005$ ).

**Discussion:** Our study demonstrated that SA-LLIF did not alter psoas muscle morphology, underlining its minimally invasive nature. However, FI of PPM significantly increased over time despite the lack of direct tissue damage to posterior structures, suggesting an ongoing inflammatory and/or pain-related response. Further studies are needed to identify contributing factors for significant changes in PPM morphology and to assess whether these changes affect surgical outcomes after SA-LLIF.

**P 050**

**Evaluation of lateral recess stenosis under axial loading using upright MRI**

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**Introduction:** Nerve root compression due to lateral recess stenosis is exacerbated under axial loading and may cause radicular pain symptoms exclusively in the standing position. Therefore, the underlying lateral recess stenosis may go undetected in standard MRI usually performed in the supine position. This work investigates the imaging of the lateral recess while standing (upright MRI) compared with standard supine MRI (conventional MRI).

**Methods:** Ten consecutive patients were prospectively included who had markedly increasing radicular pain while standing and no clear causal findings on conventional supine MRI (SIEMENS, 3T, 3D T2 SPACE). These patients additionally underwent lumbar upright MRI in the standing position (Esaote G-scan, 0.25T, 3D HYCE). In addition to the clinically most likely affected lateral recess (index recess), all remaining lumbar lateral recesses (L1 to S1) were quantified in 4 axial slices in anterior-posterior direction (Figure 1). The mean values of the standing versus supine recessus measurements were compared using the Wilcoxon matched-pairs signed rank test.

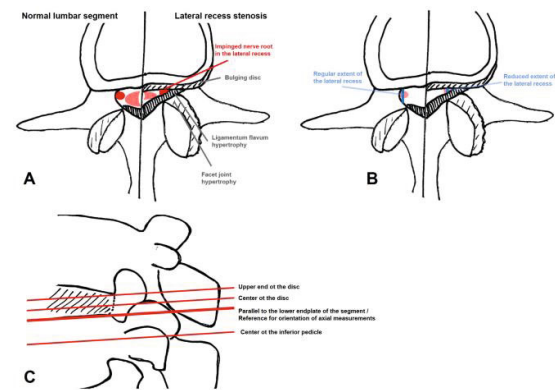
**Results:** The clinically most frequently suspected index recessus of the 10 patients (5m/5f, 65  $\pm$  15 years) was located in segment L4-5 (50%). The extent of the lateral recess decreased significantly on upright MRI compared to conventional supine MRI for both the index recesses ( $5.1 \pm 1.0$  versus  $5.5 \pm 0.9$  mm,  $p=0,04$ ) and the entirety of all lumbar lateral recesses ( $5.6 \pm 1.3$  versus  $6.1 \pm 1.2$  mm,  $p=0,01$ ) (Figure 2). In addition, within the upright MRI as well as supine MRI examinations, there was a significantly more pronounced lateral recess stenosis in the index recesses compared to all lateral recesses ( $p<0.05$  respectively).

**Discussion:** Upright MRI, as a non-invasive diagnostic modality, is capable of demonstrating an increase in lateral recess stenosis under axial loading. However, the reduced image quality of the applied 0.25 Tesla scanner, the limits of the measurement accuracy as well as the restrictedly investigable patient collective have to be taken into account in a limiting manner. The extent to which upright MRI can support future surgical indications as a complementary imaging modality remains to be investigated.

**Figure 1:**

Nerve root compression due to stenosis of the lateral recess (A, right). Measurement of the extent of the lateral recess in axial slices in anterior-posterior direction at the level of the affected nerve root (B). Orientation of the 4 defined slices for measuring the extent of the lateral recess (C).

**Fig. 1**



**Fig. 2**

Extent of the lateral recess		upright-MRI	Conventional MRI	p-value
All lumbar segments, mm	Mean $\pm$ SD (mm)	5.6 $\pm$ 1.3	6.1 $\pm$ 1.2	< 0.05
	95% Confidence Interval	5.33 - 5.82	5.84 - 6.29	
Index-Recess, mm	Mean $\pm$ SD (mm)	5.1 $\pm$ 1.0	5.5 $\pm$ 0.9	< 0.05
	95% Confidence Interval	4.41 - 5.73	4.95 - 6.11	

**P 051**

**Sensitivity of different imaging studies in subaxial cervical spine injuries**

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**Introduction:** In 30% of polytrauma patients there are injuries to the spine. A standardised CT polytrauma scan is performed as part of the emergency diagnosis. This study compared the sensitivity of imaging examination modalities computed tomography (CT),

dynamic fluoroscopy (DL), magnetic resonance imaging (MRI) for the detection of cervical spine injuries requiring intervention in order to establish diagnostic algorithms.

**Methods:** Retrospectively, 30 patients with cervical spine injuries requiring surgery were included in this study with complete radiological diagnosis in all 3 modalities. Inter- and intraobserver variability were tested by correlation analysis and the significance of sensitivity was verified by the chi-square test. The significance level is  $p < 0,05$ .

**Results:** The sensitivity was 43% for CT, 76% for DL and 95% for MRI. CT in conjunction with DL was able to detect 76% of the injuries. Together with MRI, the sensitivity of CT was 95%. Only the combination of all 3 modalities was it possible to detect all injuries. With CT alone, it was only achievable to detect one half of the cervical injuries, which required intervention.

**Discussion:** CT alone does not provide sufficient diagnostic certainty in the detection of unstable cervical spine injuries. Only by combining CT with DL and MRI can the destructions be reliably identified. This finding of the present study has clinical relevance for the treatment of polytraumatised patients.

**P 052**

ePoster withdrawn

**P 053**

**A positional magnetic resonance imaging study of redundant nerve roots in lumbar spinal stenosis: The prevalence in standing position decreases by half in supine and almost to zero in flexed seated position**

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**Introduction:** This retrospective study investigated the influence of posture on lordosis (LL), length (LSC) and dural cross-sectional area (DCSA) of the lumbar spinal canal, anteroposterior diameter (APD L1-L5), and the prevalence of redundant nerve roots (RNR) using positional magnetic resonance imaging (MRI) (0.6 T). The clinical significance of RNR is that the majority of studies have observed a worst post-surgery outcome in patients with RNR compared with patients without RNR.

**Methods:** Sixty-eight patients with single-level degenerative central lumbar spinal stenosis (cLSS) presenting with RNR in the standing position (STA) were also investigated in supine (SUP) or neutral seated (SIT) and flexed seated (FLEX) positions (Fig. 1). Additionally, 45 patients complaining of back pain and without MRI evidence of LSS were evaluated. Statistical significance was set at  $p < 0.05$ .

**Results:** Controls (A) and patients with cLSS (B) were comparable in terms of mean age ( $p=0.88$ ) and sex ( $p=0.22$ ). The progressive transition from STA to FLEX led to a comparable decrease in LL ( $p=0.97$ ), an increase in LSC ( $p=0.80$ ), and an increase in APD L1-L5 ( $p=0.78$ ). The APD of the stenotic level increased disproportionately between the different postures, up to 67% in FLEX compared to 29% in adjacent non-stenotic levels ( $p < 0.001$ ). Therefore, the prevalence of RNR decreased to 49%, 26%, and 4% in SUP, SIT and FLEX, respectively (Tab. 1).

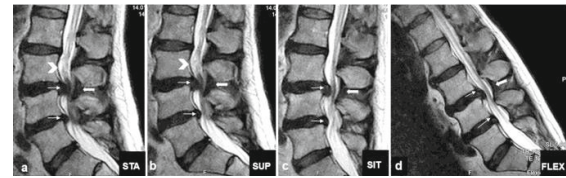
**Conclusions:** 1. The prevalence of RNR in standing position was underestimated by half in supine position; 2. In contrast, if in the MRI-SUP investigation stenosis should be maximized to resemble the findings in STA, the conventional psoas-relaxed position should be substituted with a combination of straightening legs and placing a lumbar pillow underneath the back; 3. Body postures modified LL, LSC, and APD similarly in patients and controls; 4. Stenotic levels compensated for insufficient intraspinal volume with a disproportionate enlargement when switching from the STA to FLEX.

**Fig 1**

A 73-year-old man presented with neurogenic claudication. **a** STA: RNR (arrowhead) cranial to the pincer stenosis caused by the

buckling of discs (slim arrows) and yellow ligament (thick arrow). **b** No relevant difference in SUP was observed. **c** In SIT partial flattening of discs and yellow ligament with increase in the APD and resolution of RNR was observed. **d** In FLEX enlargement of the stenotic level and complete resolution of the RNR

**Fig. 1**



**Fig. 2**

**Tab. 1 Comparison of LL (°), LSC (mm), and APD (mm) between patients and controls in four different body postures and prevalence of RNR**

(Mean ± SD) [95% CI]	STA - LL	SUP	SIT	FLEX
Patients	45.01 ± 10.97 [42.36, 47.67]	42.29 ± 9.37 [39.33, 45.25]	23.69 ± 10.92 [21.05, 26.33]	8.59 ± 7.96 [6.66, 10.52]
Controls	51.11 ± 11.33 [47.71, 54.52]	45.42 ± 9.75 [42.49, 48.35]	29.84 ± 13.93 [25.66, 34.03]	10.84 ± 11.86 [7.28, 14.41]
p - value	<b>0.005</b>	0.134	<b>0.015</b>	0.228

(Mean ± SD) [95% CI]	STA - LSC	SUP	SIT	FLEX
Patients	156.37 ± 11.97 [153.47, 159.27]	157.90 ± 11.92 [154.14, 161.66]	163.53 ± 11.95 [160.64, 166.42]	168.82 ± 11.81 [165.96, 171.68]
Controls	153.33 ± 11.03 [150.02, 156.65]	155.89 ± 10.99 [152.59, 159.19]	162.47 ± 12.95 [158.58, 166.36]	169.02 ± 13.29 [165.03, 173.01]
p - value	0.117	0.417	0.655	0.934

(Mean ± SD) [95% CI]	STA - APD	SUP	SIT	FLEX
Patients	10.95 ± 2.92 [10.24, 11.66]	10.90 ± 2.60 [10.07, 11.72]	11.45 ± 2.39 [10.78, 12.03]	12.81 ± 2.72 [12.15, 13.47]
Controls	12.63 ± 2.49 [11.88, 13.37]	12.99 ± 2.67 [12.19, 13.79]	12.81 ± 2.20 [12.15, 13.47]	14.14 ± 2.69 [13.33, 14.59]
p - value	<b>0.002</b>	<b>&lt; 0.001</b>	<b>0.003</b>	<b>0.012</b>

	STA - RNR	SUP - RNR	SIT - RNR	FLEX - RNR
%	100	49	26	4
[95% CI]	-	[32.88, 64.87]	[11.11, 46.28]	[0.92, 12.36]

LL = Lumbar Lordosis angle L1/S1; LSC= Length Spinal Canal L1-S1; APD L1-L5 = Sum of the Antero-Posterior Diameter at the mid disc levels; **Bold p < 0.05**

**P 054**

**Navigation in Kyphoplasty – Analysis of exposure to radation of patient and surgical team**

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**Introduction:** There are data that show improved precision and decreased exposure to radiation for patients and surgical team if implantation of pedicle screws is guided by navigation, especially in minimally invasive techniques. There is presently no conclusive data on kyphoplasty. It is not known if image acquisition for navigation in kyphoplasty does not even lead to more exposure to radiation than the conventional technique.

The hypothesis of this study was, that navigation in kyphoplasty does not lead to more exposure to radiation than the conventional technique.

**Methods:** We included 26 consecutive patients who have been treated by kyphoplasty for a vertebral compression fracture in our institution from 01.2007 to 03.2022. Data of 16 consecutive patients who were treated by conventional fluoroscopic kyphoplasty were collected retrospectively, data of 10 consecutive patients who were treated by navigated kyphoplasty were collected prospectively.

We excluded patients with incomplete sets of data and patients who would not or who could not consent to participate in the study. In all 26 patients the same image intensifier (Arcadis Orbic 3D, Siemens) and the same kyphoplasty system (Affirm, Globus Medical) were applied.

Statistical analysis was performed by SPSS 25. Since data showed normal distribution, students *t* – tests were performed. Descriptive data were given as mean and standard error of mean.

**Results:** Dosis of radiation for the patient was 124.5 cGy\*cm<sup>2</sup> (30.8) in the conventional technique and 112.7 cGy\*cm<sup>2</sup> (16.5) in the navigated technique. The difference was not significant (*p*>0.05) with a low statistical power (0.34).

Dosis of radiation for the surgical team was 124.5 cGy\*cm<sup>2</sup> (30.8) in the conventional technique and 27.1 cGy\*cm<sup>2</sup> (4.1) in the navigated technique. The difference was significant (*p*<0.01) with a high statistical power (0.99).

Time of surgery was 46.8 min (30.8) in the conventional technique and 44.4 min (7.5) in the navigated technique. The difference was not significant (*p*>0.05) with a low statistical power (0.25).

There were no perioperative complications.

**Discussion and Conclusion:** In kyphoplasty the navigated technique did not lead to a higher dose of radiation than the conventional technique. In our group of patients we saw a minor and not significant reduction of dose of radiation for the patient of 9.5% and a major and statistically significant reduction of dose of radiation for the surgical team by 78.2%. In our institution we now prefer the navigated technique before the conventional technique of kyphoplasty.

#### P 055

##### Cadaveric study of ergonomics and performance using a robotic exoscope with a head-mounted display in spine surgery

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**Introduction:** Surgeon comfort is affected by long-term misalignment when using conventional microscopes. Monitor-based exoscopes could provide a solution as they allow a more favorable posture as already shown in pre-clinical studies. The aim of this study was to test the usability and comfort of a novel head-mounted display (HMD) based exoscope in a simulated OR-setting.

**Material/Methods:** A total of 21 neurosurgeons naïve to the device participated voluntarily. After a standardized 10-step microsurgical training exercise, participants were asked to perform a single-level lumbar decompression on human cadavers using the exoscope. Subsequently, all participants completed a comfort and safety questionnaire. For the objective evaluation of the performance, all interventions were videotaped and were retrospectively analyzed. The surgical videos were analyzed for completion of the decompression, the number of incorrect commands to the robot and necessary display readjustments.

**Results:** 14 men and 7 women with a mean age of 34 (interquartile rate [IqR] 30.5; 39.5) were participating in the study. The average time per decompression (start of the laminotomy to finalized decompression) was 15 min. (IqR 9.6; 24.2); 3 participants (14%) had to terminate the procedure prematurely. A significantly higher incidence of back/neck pain (*p*=0.002 for back, *p*=0.046 for neck pain) as well as an increased frequency of HMD readjustments (*p*=0.045) and decreased depth perception (*p*=0.03) were found in the dropouts. The median rate of incorrectly executed commands for the exoscope was 23% for the first and 19%, 10%, and 22% for the second, third and fourth quarters of the overall procedure time. 11 participants (52%) required HMD readjustment during the procedure while 33% required other technical assistance. Overall, the surgeons' satisfaction with the exoscope was 84% (IqR 37.5; 46.0).

**Discussion:** With the help of a standardized, pre-interventional training, it was possible to perform sufficient spinal decompression using the HMD-based exoscope. Incorrect HMD-setup at the start of the procedure may lead to discomfort. The high overall satisfaction of the surgeons using the HMD-based exoscope may serve as start for a smooth transition towards new visualization devices.

#### P 056

##### Implementation of a three-dimensional (3D) robotic digital microscope (AEOS) in spine procedures

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**Objective:** 3D-exoscopes have been introduced to overcome shortcomings of operative microscopes. Prior clinical studies demonstrated high satisfaction with magnification and illumination combined with high level of ergonomics. We investigated the clinical use in spine procedures.

**Methods:** We treated patients with various spine diseases in a neurosurgical department of a tertiary spine center according to current standard of care over four weeks period of time. Microsurgical procedures have been performed with Aesculap AEOS 3D microscope. Three neurosurgeons with different levels of experience and microsurgical skills were instructed and completed a questionnaire consisting of 43 items concerning intraoperative handling following the procedures.

**Results:** 17 patients (35 % male/ 65 % female) with a median age of 70 years [CI 47-86] and median BMI of 25.8 [CI 21-33] with numerous spine indications with different level of complexity (35% low/35 % medium/ 30 % high according to the German Spine Society Score) were analyzed. 6 decompression surgeries, 3 anterior fusions, 4 corpectomies, 3 disc prosthesis and 1 tumor resection cases were performed in the cervical (35%), thoracic (24%) and lumbar (41 %) segments respectively. We experienced a moderate median surgical time of 94 minutes [CI 59-186 minutes] and median blood loss of 300 ml [100-3000 ml]. Setup conflicts were associated with adjustments of the monitor position or additional equipment (e.g. fluoroscopy in fusion surgery) (*p*=0.05). Image resolution, image sharpness and 3D-depth perception were absolutely satisfactory for all surgeons in all procedures (*p*=0.05). All surgeons indicated that the control of the exoscopic arm was easy and enabled a better surgical corridor without blocking the working zone (*p*=0.05). No eyestrain or disturbance of the hand-eye coordination affected the surgeon's performance (*p*=0.05). However, higher complexity of procedures was associated with higher levels of frustration (*p*=0.07) and anxiety (*p*=0.62).

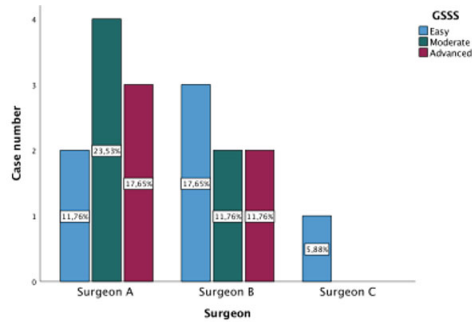
##### Conclusion:

The implementation of a 3D-exoscope in minimally invasive spine procedures appears to be highly beneficial due to improved depth of field, illumination, magnification as well as ergonomics for the surgeon.

Fig. 1



Fig. 2



## P 057

## Forgotten spinal pathologies

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Examinations of skeletons from (pre)historic times can show spinal pathologies that are rare today or are no longer observed in an advanced stage. The aim of this presentation is to show the state of health of our ancestors and to make today "forgotten" diseases of the spine more present.

The skeletons come from archaeological excavations over a large period from the Neolithic to the early modern period. The bone pathologies are presented macroscopically, microscopically and, if necessary, also radiologically.

The case collection presented includes two groups of diseases whose diagnosis can be made with reasonable assumptions (e.g., through molecular genetic detection of the pathogen or specific skeletal pathology):

- Infections: spinal tuberculosis (Fig. 1 and 2)
- Injuries from weapons: Arrow, sword or axe

Palaeopathological examinations can provide insights into spinal diseases that are rare today and thus sharpen the diagnostic view.

Fig. 1 Multiple marginal bony cavities of the lower thoracic spine in (productive)tuberculosis

Fig. 2 Complete osteolysis of several thoracic vertebral bodies in (exudative) tuberculosis

Fig. 1



Fig. 2



## P 058

Treatment Failure in Vertebral Osteomyelitis – is it all about *Staphylococcus aureus*?A. Yagdiran<sup>1</sup>, D. Jochimsen<sup>2</sup>, N. Kernich<sup>1</sup>, J. Herden<sup>3</sup>, P. Eysel<sup>1</sup>, K. Eberhardt<sup>4</sup>, \*N. Jung<sup>2</sup><sup>1</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>2</sup>Universitätsklinikum Köln, Klinik I für Innere Medizin, Köln, Deutschland<sup>3</sup>Universitätsklinikum Köln, Urologie, Köln, Deutschland<sup>4</sup>Universitätsklinikum Hamburg-Eppendorf, Institut für Tropenmedizin, Hamburg, Deutschland

**Introduction:** Vertebral osteomyelitis (VO) is mainly caused by *Staphylococcus aureus* (SA), while enterococci and streptococci (ENST) are also responsible for a significant proportion of VO, particularly in elderly patients. Data on VO caused by SA show a tendency for worse outcome, whereas data on VO caused by ENST are scarce. For this purpose, our study compares characteristics of patients with VO caused by SA or ENST in order to analyze risk-factors for treatment failure.

**Methods:** We conducted a prospective monocentric study including VO patients from 2008-2020. Primary outcome was treatment failure defined as death or relapse within one year (T1).

**Results:** Data of 130 VO-patients (SA=95; ENST=35) were available at T1. Treatment failure occurred in 37% of SA- and 23% of ENST-patients. On multivariate analysis SA (OR:3.12;95%CI:1.09–10.53; p=0.046), Charlson Comorbidity Index (=CCI, OR:1.31;95%CI:1.11-1.58; p=0.002) and infectious endocarditis (=IE, OR:4.29;95%CI:1.23-15.96; p=0.024) were identified as independent risk-factors for treatment failure.

**Conclusion:** Every third patient with VO caused by SA or ENST dies within one year. Patients with VO caused by SA or concomitant IE and/or a high CCI score are at high risk for treatment failure. Our findings underline the importance of echocardiography in patients with VO caused by gram-positive pathogens.

## P 059

## Therapy and course of cervical spondylodiscitis:

## A monocentric retrospective study

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**Objective:** Cervical spondylodiscitis is uncommon, with an incidence of 0.5 to 2.5 per 100,000 population, but is potentially hazardous because it cause the highest rate of neurological impairment and it has highest potential for permanent damage. Radical surgical treatment of infection with fusion of the affected segment and antibiotic therapy are the gold standard in many spine centers.

**Methodology:** In this study, all patients who suffered from cervical spondylodiscitis between 01/2017 and 05/2022 and were treated in our university hospital were retrospectively included and their clinical and radiological parameters were evaluated.

Descriptive statistics were performed using SPSS, and relevant correlations were examined using the t-test for independent samples and the chi-square test.

**Results:** 24 patients (7 females/17 males) with a mean age of 66 years, a median BMI of 25, a median ASA score of 3 and a median Charlsson Comorbidity Index (CCI) of 5 were identified during the period. 17 (71%) patients suffered from sepsis on admission, 17 (71%) had an epidural abscess on imaging, and 5 patients (21%) had another discitis focus in a distal spinal segment. The presence of epidural abscesses was significantly associated with sepsis ( $p=0.03$ ) and myelopathy symptoms ( $p=0.00$ ). Septic status correlated significantly with the occurrence of discitis in other segments ( $p=0.02$ ), higher CCI ( $p=0.03$ ) and Clavien Dindo scores ( $p=0.01$ ), as well as longer ICU stay ( $p=0.04$ ) and the occurrence of nonunion ( $p=0.06$ ). The most commonly detected germ was a multisensitive *Staphylococcus aureus* (10 patients, 42%). 16 patients (67%) underwent ventral surgery, 5 patients (21%) combined ventrodorsal surgery and one (4%) dorsal surgery. 2 patients (8%) refused any surgical treatment. A total of 6 patients (25%) died of their disease after a median of 20 days despite antibiotic-based therapy. The follow-up data from 19 patients (79%) were available with evidence of permanent neurological damage e.g. radiculopathy, myelopathy, or complete sensorimotor cross-section in 9 patients (38%).

**Conclusion:** In summary, cervical spondylodiscitis is a serious infectious disease that occurs in multimorbid elderly patients and, despite adequate surgical and antibiotic treatment, is often associated with permanent neurological damage and a fatal outcome.

#### P 060

##### 3D segmentation to measure bone volume of infected vertebral bodies in pyogenic spondylodiscitis

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**Introduction:** In pyogenic spondylodiscitis, inflammatory processes lead to destruction of the intervertebral disc and the adjacent vertebral body. The extent of bone loss influences the stability of the spine and is therefore important for therapeutic decisions. The aim of the study was to quantify bone loss using a previously described mathematical method.

**Material/ Methods:** The data of all adult patients treated for pyogenic spondylodiscitis in the thoracolumbar region in our orthopedic traumatology center between 2000 and 2020 were retrospectively analyzed. CT-DICOM data and information on the causative pathogens were extracted. Volume measurement was performed using the open-source segmentation software (3D) Slicer.

A destruction ratio "t" was calculated as the ratio between the volume of an infected vertebral body measured by 3D volumetry and its normative volume predicted by linear regression on a case-specific basis.

**Results:** 31 patients met the inclusion criteria, including 15 females and 16 males. The mean age was  $67\pm 9.2$  years. The mean BMI was  $32.4\text{ kg/m}^2$ .

The L2 vertebral body was the most frequently infected (Fig. 1). The lumbar spine (LS) was more frequently affected than the thoracic spine (TS).

The average destruction quotient over the entire spine was  $0.91\pm 0.3$  (TS: 0.82, LS: 0.97). This corresponds to an average bone volume loss of 9% (Fig.2). The maximum value was 1.71, the minimum value 0.42.

The most frequent pathogens were staphylococci (58.6%), especially *Staph. aureus*, followed by enterobacteria (17.2%) and enterococci (10.3%). Subgroup analysis showed a mean volume change of -18.0% in cases with gram-positive pathogens and of +1.4% with gram-negative pathogens ( $p=0.303$ ). At the TS t was measured as  $77.1\pm 27.5$ , at the LS  $93.6\pm 41.9$  ( $p=1.01$ ).

**Discussion:** The method for measuring vertebral body volumes with 3D slicers has already been applied and can be used (Egger et al., Sage Open Medicine, 2017).

It could be shown that bone volume decreases on average in pyogenic spondylodiscitis.

We are not aware of any comparable approach in the literature for measuring and describing bone volume destruction of the spine.

Fig. 1 Overview of the localizations of infected vertebral bodies in pyogenic spondylodiscitis, y: Number (n), x: Localization

Fig. 2 Average destruction quotients for the bone volume of vertebral bodies with pyogenic spondylodiscitis. Displayed as a boxplot, divided according to the thoracic spine, lumbar spine and entire spine. y: Destruction quotient (t), x: Localization. The medians, upper and lower quartiles are shown. The whiskers show the 95 confidence interval.

Fig. 1

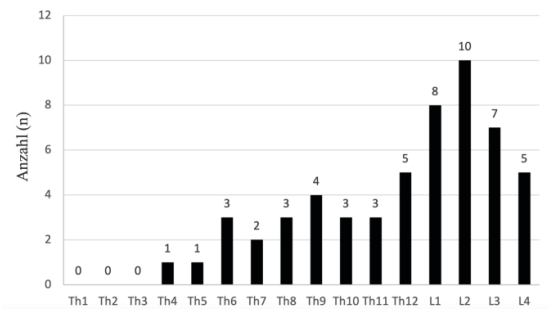
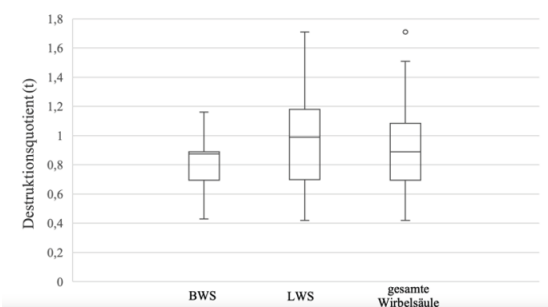


Fig. 2



#### P 061

##### Reliability of classification systems for spondylodiscitis and their correlation with quality of life in surgically treated spondylodiscitis-patients

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**Background:** Classifications of severity for spondylodiscitis (SD) usually incorporate various radiologic features – e. g. bony destruction, instability, (epidural) abscesses – and the status of neurologic impairment. However, other parameters that are important for a comprehensive assessment of SD, such as back- and legpain, function/disability or overall quality of life (QoL), are not considered. We aim to evaluate the reliability of three common surgical SD classifications and to analyse their correlation with pain, disability and QoL.

**Materials and Method:** Eighty-three patients (28 females, 55 males; mean age 64 years) from a prospective register of surgically treated spondylodiscitis between 2008 and 2019 with available MRI and X-ray imaging, data on neurologic status, pain, disability (ODI, COMI) and QoL (SF-36, EQ-5D) and a minimum follow-up of one year were retrospectively classified according to the Akbar, Homagk and Pola severity scores by two independent senior spine surgeons. Interrater reliability, correlation among the scores and

correlation between SD severity and pain, disability and QoL were calculated.

**Results:** Mean preoperative backpain was 9/10, ODI was 77, COMI was 8.9, SF-36 was 28 and EQ-5D was -0.95. Eight patients (9%) were classified as Akbar 0, IA, IB or II, 52 (63%) as IIIA, 9 (11%) as IIIB and 14 (17%) as IV. Three patients (4%) were classified as Homagk IA, 22 (27%) as IB, 4 (5%) as IIA, 37 (45%) as IIB and 17 (20%) as IIIB. Eight patients (10%) were classified as Pola A, 27 (32%) as B, 10 (23%) as C.1, 14 (17%) as C.2 and 15 (18%) as C.3-4. Interrater reliability of the classifications was  $\kappa=0.63$  for Akbar,  $\kappa=0.64$  for Homagk and  $\kappa=0.69$  for Pola. Correlation of Akbar with Pola and Homagk was moderate ( $\rho=0.41$ ;  $\rho=0.46$ ), correlation of Pola with Homagk was high ( $\rho=0.66$ ). There was no correlation between any classifications and QoL, function or backpain.

**Discussion:** While available SD classifications have a good interrater reliability and moderate to high correlation with each other, they lack correlation with QoL and other clinical factors like pain and disability. Since these are important in comprehensively evaluating SD, they should be incorporated into future SD classifications to facilitate better treatment algorithms.

#### P 062

##### Pathological wound healing disorders after spinal surgery-relationship between operation duration and isolated germ

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**Introduction:** Surgical interventions are now established treatment options for a number of spinal pathologies. Especially in the last decades, the number of operations in this area has increased significantly and with it the number of possible perioperative complications. Wound complications and infections are particularly noteworthy. The aim of the present work was to evaluate a connection between the causative germ and the duration of the operation.

**Methods:** In a retrospective study over a period of two years, all patients with postoperative wound healing disorders were included. Patients with spondylodiscitis and negative microbiological findings were not included. In addition to descriptive characteristics (gender, age, BMI), the duration of the operation, the administration of intra-operative antibiotics, the main diagnosis, the postoperative course of the infection parameters (CRP & WBC) and the responsible pathogens were analyzed. The statistical evaluation was carried out using the SPSS statistics program (IBM SPSS Version 20, 76 Chicago, IL, USA).

**Results:** A total of 57 patients (m: n= 30, 52.6%; f: n= 27, 47.4%) with postoperative wound healing disorders/infections were included in the observation period. The mean age was 64 years (range 14-85 years), the mean BMI 29.4 kg/m<sup>2</sup>, with 73% (n=42) of the patients being overweight. The leading diagnoses were spinal canal stenosis in 14 cases (24.6%), followed by herniated discs (n=8; 14%), foraminal stenosis (n=7; 12.3%) and metastases (n=7; 12.3%). The mean operation time was 113.4 5+/-74.73 min (range 33-285 min). The most frequently isolated germ was S.aureus (n=5, 8.8%), followed by S.haemolyticus and S. hominis (n=2; 3.5%). In 73.7% of the cases no germ could be isolated. There was a significant connection (ANOVA<0.05) between the duration of the surgical intervention and the postoperatively detected germ (S.epidermidis: 40 minutes; Candida tropicalis: 48 minutes, S.hominis 68.5 minutes, S.aureus 97 .8 minutes, Corynebacterium agnes, E. faecalis, S.warneri, Acinetobacter: 161 minutes, E. coli: 221 minutes, S.haemolyticus: 226 minutes, S.capitis: 276 minutes, E. faecalis: 285 minutes). There was no significant correlation between specific bacterial infections and gender, BMI and ASA score (Chi2 p> 0.05).

**Discussion:** The present work was able to show a significant connection between the duration of the surgical intervention and the detected germ in patients with postoperative wound healing disorders. The results can serve as an aid in the selection of a suitable antibiotic therapy in the case of an existing wound healing disorder.

#### P 063

##### Treatment results of spinal stabilisation in cirrhotic patients with spondylodiscitis – a 10-year retrospective monocentric study

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The treatment of spondylodiscitis in patients with liver cirrhosis is challenging. In particular, complications of other organ systems may occur due to cirrhosis. Coagulopathy with a simultaneous increased bleeding and thrombosis tendency should be emphasised. Taken together, this can have a negative impact on postoperative outcome, revision frequency, and survival. The aim of this study was to analyse the characteristics of patients with spondylodiscitis and cirrhosis and the treatment outcomes after spinal stabilisation in our own patient population.

We performed a query of the institutional database for coding of spondylodiscitis, liver cirrhosis, and surgical access to the spine within the last decade. We retrospectively documented diagnosis, surgery, patient age and sex, pathogen, focus, stage and complications of cirrhosis, preoperative coagulation parameters, and number of revisions and survival.

We identified 14 patients in our patient population. Most were male (n=8, 57.1%), mean age was 61 years. The most frequently detected pathogen was Staphylococcus aureus (n=4, 28.6%). No pathogen detection was possible in 5 patients (35.7%). Child-Pugh was A in none, B in 5 (35.7%), C in 4 (28.6%) and unknown in 5 patients (35.7%). The coagulation values were moderately reduced (median INR 1.2, pTT 34.9s, platelets 107 Gpt/l). There were 2 (14.2%) stabilisations of the cervical, 6 (42.9%) of the thoracic, 2 (14.2%) of thoracolumbar and 4 (28.5%) of the lumbar spine performed. A combined anterior-posterior approach was chosen in 5 (35.7%) and a dorsal approach alone in 9 (64.3%) cases. Revisions were required in 5 patients (35.7%), with 3 (21.4%) patients receiving one revision each, one (7.1%) patient receiving 3 revisions and another (7.1%) receiving more than 3 revisions. Reasons for revisions were material insufficiency with segment instability or secondary kyphosis in 4 cases in 3 patients and an infection of the osteosynthesis in one case. In the patient with more than 3 revisions, the causes were postoperative epidural haematoma, material loosening and cerebrospinal fluid fistula. Specific complications of cirrhosis were mostly ascites (50%), oesophageal varices (50%) and coagulation disorders (35.7%). Surgical spinal stabilisation of patients with spondylodiscitis and cirrhosis are highly complicating. To date, there are no recommended procedures in this particular patient population. In our opinion, the indication for surgery should be evaluated extremely carefully, preoperative coagulation should be optimized, and the underlying disease should be treated in an optimal manner.

#### P 064

##### Postoperative prolonged mechanical ventilation in patients with surgically treated pyogenic vertebral osteomyelitis – a surrogate endpoint for early postoperative mortality

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**Introduction:** Surgical procedures with spinal instrumentation constitute a prevalent and occasionally highly indicated treatment modality in patients with pyogenic vertebral osteomyelitis (PVO). However, surgical therapy might be associated with the need of prolonged postoperative intensive care medicine which in turn might impair intended operative benefit. We therefore analyzed postoperative prolonged mechanical ventilation (PMV) as an indicator variable for such intensive care treatment with regard to



potential correlations with mortality in this vulnerable patient cohort.

**Methods:** 177 consecutive patients received stabilization surgery for pyogenic vertebral osteomyelitis between 2012 and 2018 at the authors' neurosurgical department. PMV was defined as postoperative mechanical ventilation of more than 24 hours. A multivariate analysis was performed to identify independent predictors for 30-day mortality.

**Results:** 23 out of 177 patients (13%) suffered from postoperative PMV. 30-day mortality rate was 5%. Multivariate analysis identified "spinal empyema" (p=0.02, OR 0.8, 95% CI 0.03-0.8), "Charlson comorbidity index > 2" (p=0.04, OR 0.7, 95% CI 0.07-1.0), "early postoperative complications" (p=0.001, OR 0.9, 95% CI 0.01-0.3) and "PMV > 24 hrs" (p=0.001, OR 0.8, 95% CI 0.02-0.4) as significant and independent predictors for postoperative early mortality.

**Conclusions:** The present study indicates postoperative PMV to significantly correlate to elevated early postoperative mortality rates following stabilization surgery for pyogenic vertebral osteomyelitis. These results might entail further scientific efforts to investigate PMV as a so far underestimated negative prognostic factor in surgical treatment of pyogenic vertebral osteomyelitis.

Fig. 1

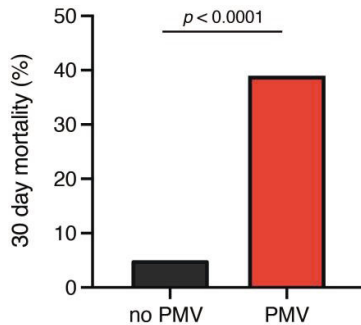


Fig. 2

Table: Factors associated with postoperative PMV following stabilization surgery for pyogenic vertebral osteomyelitis\*

	Patients without PMV n=154	Patients with PMV n=23	p-value
Median Age (yrs) **	72 (60-78)	73 (68-77)	0.35
Female sex	62 (40)	6 (26)	0.25
Location of disease			0.03
Cervical	15 (10)	7 (30)	0.01
Thoracic	31 (20)	5 (22)	0.79
Lumbar	98 (64)	9 (39)	0.04
Combined	10 (6)	2 (9)	0.66
Level of disease			<0.0001
1-2	140 (91)	11 (48)	
> 2	14 (9)	12 (52)	
Associated spinal empyema	45 (29)	14 (61)	0.004
Median CCI	1 (0-3)	3 (1-4)	0.004
Preoperative anticoagulant medication	33 (21)	14 (61)	0.004
Preoperative neurological deficit	39 (25)	11 (48)	0.04
Preoperative systemic inflammation levels			
CRP > 10 mg/l	132 (86)	23 (100)	0.08
WBC > 12 G/l	17 (11)	9 (40)	0.002
Median time of surgery	243 (185-317)	274 (189-393)	0.27
Early postoperative complications	24 (16)	9 (39)	0.02
PSIs	9 (6)	5 (22)	0.02
HACs	10 (6)	4 (17)	0.09
Specific SSCs	5 (3)	0 (0)	1.0
30-day mortality	7 (5)	9 (39)	<0.0001

\*Values represent the number of patients unless indicated otherwise (%).

CCI, Charlson comorbidity index; CRP, c-reactive protein; HAC, hospital-acquired conditions; IQR, interquartile range; PSIs, patient safety indicators; SSCs, spinal surgery related complications; WBC, white blood cells; yrs, years. \*\* Median (IQR).

P 065

What do we know about Spondylodiscitis in children?

A retrospective study

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**Introduction:** Pediatric spondylodiscitis (PSD) is a rare disease with a major impact on mobility and functional status. Data concerning demographic and microbiological characteristics, clinical course, treatment and outcome are scarce. Therefore, the aim of this study was to present clinical experiences of a third-level hospital in PSD and compare these with adult spondylodiscitis (ASD).

**Methods:** We conducted a retrospective monocentric study of KSD patients from 2009 to 2019 to perform a detailed clinical presentation.

**Results:** Of a total of 10 PSD patients, most of the infants presented with unspecific pain such as hip pain or a limping, misleading an adequate diagnosis of spine origin. Eight patients could be treated conservatively whereas surgery was performed in two cases with one case of tuberculous PSD. The causative agent was detected in three of the patients.

**Discussion:** The diagnosis of PSD is often difficult since clinical symptoms are unspecific and causative pathogens often remain undetected. Nevertheless, empirical anti-infective therapy also seems to be effective. Based on recent studies clinicians should be encouraged to keep the duration of anti-infective therapy in children short. Since comorbidities are not presented in PSD it is unclear which children suffer from PSD, thus studies are necessary to identify predisposing factors for PSD. In our study, PSD differs from ASD in several aspects. Therefore, specific guidelines for PSD would be desirable.

P 066

The effect of outpatient parenteral antimicrobial therapy for patients with spinal infection

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**Objective:** Outpatient parenteral antimicrobial therapy (OPAT) is a safe method of delivering intravenous antimicrobial therapy for patients with spinal infection in whom treatment is possible without hospitalization. However, the clinical benefit of avoiding hospitalisation is unclear.

**Methods:** In this study patients with spinal infection and antimicrobial treatment without hospitalisation between 2018 and 2021 were retrospectively analyzed. The duration of short-term antimicrobial treatment for skin and soft tissue infections as well as complex infections with long-term antimicrobial treatment such as spinal bone or joint infection were analyzed. All included patients were discharged with a peripherally inserted central catheter (PICC) line. Before discharging all included patients receive a training session for safely administer their medication through the PICC-line. The duration of OPAT as well as the rate of readmission after OPAT was analyzed.

**Result:** We identified 52 patients who were treated after spinal infection by delivering intravenous antimicrobial therapy in whom further care was possible without hospitalisation. In 35 cases (69.2%) complex spinal infection such as spondylodiscitis or spinal empyema were detected. In 23 of the 35 patients (65.7%), treatment consisted of surgical debridement of the infected vertebrae and disc material, fusion, and spinal instrumentation. After surgical treatment hospital stay for these cohort was on average 12 days. The remaining patients (17 patients) were treated

for soft tissue or skin infection. The hospital stay for these cohort was on average 11 days. In most cases (64.4%) gram-positive organisms were isolated. The most common pathogens were coagulase-positive staphylococcus aureus followed by other staphylococcus species. For all included patients after discharging OPAT was performed on average for 41.3 days. The duration for short-term antimicrobial treatment was done for 10.8 days, and for complex infections for 25.1 days. In one case readmission caused by treatment failure was necessary. Adverse effects of OPAT was not observed.

**Conclusion:** OPAT is a cost-effective use of hospital resources and allows patient with spinal infection a centred care closer to home while avoiding long hospitalisation.

#### P 067

##### Diagnostic sensitivity of blood culture, intraoperative specimen, and computed tomography-guided biopsy in patients with spinal infections

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**Objective:** Successful treatment of spinal infections (SI) depends on early detection of causative pathogens. In patients with SI, pathogen identification is commonly performed either via blood cultures, intraoperative specimens, and/or image-guided biopsies. We aimed to compare the sensitivity of three procedures and to evaluate the influence of prior antibiotic treatment on pathogen detection in SI patients.

**Methods:** All patients with spondylodiscitis (SD) and/or isolated spinal epidural abscess (ISEA) who underwent surgical treatment between 2002 and 2021 were enrolled. Detailed clinical, radiological, laboratory and microbiological analysis was performed in all patients.

**Results:** Pathogens were identified in 92% of SI patients (192/208 cases). The diagnostic yield varied by procedure, being lowest for CT-guided biopsies at 56% (39/70 cases) followed by blood cultures at 57% (119/208 cases), while highest for intraoperative specimens at 78% (162/208 cases,  $p=.012$ ). Blood cultures showed a higher sensitivity in SD patients (SD: 64% vs. ISEA: 42%,  $p=.004$ ), while intraoperative specimens showed a higher diagnostic yield in ISEA patients (ISEA: 89% vs. SD: 73%,  $p=.007$ ). The sensitivity of all procedures combined was significantly lower in SD patients with ongoing antibiotics than without antibiotics, whereas no effect was observed in the ISEA group. Furthermore, in the ISEA group, intraoperative specimens alone had significantly higher pathogen detection than blood cultures alone (50% vs. 5%).

**Conclusion:** The diagnostic sensitivity of each procedure displays substantial heterogeneity in SI patients, depending on the procedures and infection subtype. We found that the highest diagnostic sensitivity of pathogen detection is in blood cultures in SD patients and in intraoperative sampling in ISEA patients.

#### P 068

##### Patient-specific risk factors for the need of surgical revision in the treatment of endogenous spondylodiscitis

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**Introduction:** Even though the incidence of spondylodiscitis has continuously been rising in the past years, to date there are no established guidelines for the surgical management of spinal infections. In particular, there is a lack of studies investigating perioperative complications after the surgical treatment of affected patients. Thus, we aimed at analyzing risk factors for the

occurrence of postoperative complications warranting surgical revision in patients treated for endogenous spondylodiscitis.

**Material/Methods:** Patients with an endogenous spondylodiscitis who were treated surgically at our center between January 2006 and December 2020 were included retrospectively. Clinical and radiological data were collected from electronic patient charts. Spondylodiscitis was defined by a combination of distinct radiological findings of the intervertebral disc in MRI and/or CT imaging as well as clinical findings. The performed surgeries were grouped into debridement and decompression alone and debridement, decompression, and instrumentation. Causative pathogens were identified using CT-guided biopsy, open biopsy, intraoperative tissue sampling, and/or blood cultures.

**Results:** A total of 130 patients with a mean age of  $66.3 \pm 12.5$  years were included. In 35 cases (26.9%) surgical revision was necessary and was performed within  $65.8 \pm 105.9$  days. In Table 1, an overview of studied parameters is given. The most frequent indications for revision were wound healing disorders (54.3%) followed by postoperative abscesses (17.1%), implant failure (11.4%), progressive neurological deficits (8.6%), hematomas (5.7%), and dural tears (2.9%). In the revision group, the infection was located significantly more frequently in the thoracic spine (22.1% vs. 34.3%) or in two or more parts (4.2% vs. 17.1%) of the spine ( $p=0.013$ ) compared with the group without surgical revision. In patients requiring revision surgery, *Staphylococcus aureus* (20.0% vs. 40.0%,  $p=0.020$ ) was found significantly more frequently than in patients not requiring surgical revision (Table 2). Multiple logistic regression analysis showed a significant influence of both smoking ( $B=1.613$ ,  $p=0.017$ ) and the detection of *Staphylococcus aureus* ( $B=1.500$ ,  $p=0.013$ ) on the necessity of surgical revision.

**Discussion:** While previous studies regarding the surgical treatment of spondylodiscitis have focused mainly on patient outcome, we for the first time analyzed the association of several pre- and intraoperative parameters with the need for surgical revision in the treatment of endogenous spondylodiscitis. Our results show that smoking as well as the detection of *Staphylococcus aureus* as a causative pathogen are significantly associated with the performance of surgical revision. When planning the optimal treatment for each individual patient, these factors therefore need to be taken into consideration.

Fig. 1

	No revision (n=95)	Revision (n=35)	p-value
Age	66.4±12.1	66.1±13.4	0.928
Sex (f/m)	43:52	18:17	0.532
Body-mass-index (kg/m <sup>2</sup> )	26.4±5.9	27.6±6.4	0.343
Charlson Comorbidity Index	2.8±2.8	2.5±2.5	0.845
<b>Comorbidities</b>			
Diabetes mellitus	19/95 (20.0%)	11/35 (31.4%)	0.170
Tumor	28/95 (29.5%)	8/35 (22.9%)	0.455
<b>Risk factors</b>			
Smoking	17/92 (18.5%)	12/34 (35.3%)	0.047*
Intravenous drug use	1/95 (1.1%)	1/35 (2.9%)	0.458
Initial body temperature (°C)	37.0±0.9	37.0±1.0	0.670
Back pain at rest (VAS)	4.1±2.6	4.6±2.9	0.427
Back pain moving (VAS)	5.9±2.8	6.0±2.7	0.938
<b>Laboratory parameters at admission</b>			
C-reactive protein (mg/L)	90.8±88.6	134.8±130.9	0.072
Leukocyte count (/nL)	10.2±5.7	12.3±7.4	0.080
Hemoglobin (g/dL)	11.2±2.0	11.3±1.9	0.856
<b>Localization</b>			0.013*
Cervical	6/95 (6.3%)	0/35 (0%)	
Thoracic	21/95 (22.1%)	12/35 (34.3%)	
Lumbar	64/95 (67.4%)	17/35 (48.6%)	
Disseminated	4/95 (4.2%)	6/35 (17.1%)	
<b>Initial surgery</b>			0.132
Debridement and decompression	5/95 (5.3%)	5/35 (14.3%)	
Debridement and instrumentation	90/95 (94.7%)	30/35 (85.7%)	
<b>Initial surgery</b>			
Number of segments fused	2.3±1.8	2.4±1.9	0.783
Number of instrumented vertebrae	3.2±1.4	3.1±1.7	0.809
Duration (min)	165.4±54.9	149.5±65.6	0.190
Length of hospital stay (d)	21.4±12.7	31.7±22.3	0.013*

Table 1. Demographic, laboratory, and perioperative data for included patients. Statistically significant p-values are marked with \*

Fig. 2

	No revision (n=95)	Revision (n=35)	p-value
<i>Staphylococcus aureus</i>	19 (20.0%)	14 (40.0%)	0.020*
<i>Staphylococcus epidermidis</i>	23 (24.2%)	5 (14.3%)	0.222
<i>Propionibacterium acnes</i>	7 (7.4%)	4 (11.4%)	0.486
Streptokokken	12 (12.6%)	3 (8.6%)	0.758
Enterokokken	3 (3.2%)	2 (5.7%)	0.611
<i>Escherichia coli</i>	6 (6.3%)	2 (5.7%)	1.000
Fungi	4 (4.2%)	2 (5.7%)	0.660
Other gram-positive pathogens	4 (4.2%)	2 (5.7%)	0.660
Other gram-negative pathogens	6 (6.3%)	5 (14.3%)	0.165

Table 2. Frequencies of identified pathogens in the two groups.

## P 069

**In-vitro** colonization of pedicle screws with biofilm forming bacteria – association of pedicle screw material and bacteria count\*D. Tkatschenko<sup>1</sup>, A. Trampusz<sup>2</sup>, J. S. Onken<sup>1</sup>, P. Vajkoczy<sup>1</sup><sup>1</sup>Charité – Universitätsmedizin Berlin, Klinik für Neurochirurgie, Berlin, Deutschland<sup>2</sup>Charité – Universitätsmedizin Berlin, Institut für Hygiene und Umweltmedizin, Berlin, Deutschland

**Introduction:** Screw loosening after instrumentation represents a frequent postoperative complication in spine surgery. Biofilm-forming microorganism colonization detected by sonication was identified as a possible cause for symptomatic implant ease. The association of different pedicle screw surface materials and bacteria count after colonialization was not analyzed yet.

**Material/Methods:** After preparation of a colony of *Staphylococcus aureus* three different types of pedicle screws (titanium, carbon peek and titanium with aluminium oxide coating) with the same size (ø7.5 x 50mm) which are frequently used in our department for instrumentation were inoculated. After 24 hours of breeding the different screws were sonicated and the accumulated material was diluted and planted on agar plates and once again incubated for 24 hours. After incubation bacteria forming colonies were counted.

**Results:** Three screws for every different surface type were used. The dilution -3 was best suited for bacteria forming colonies count. Analyzing this dilution, the sonication fluid from the titanium screws formed 21 colonies, the sonication fluid from the carbon peek screws formed 56 colonies and the sonication fluid from the titanium with aluminium oxide coating screws formed 38 colonies on average.

**Discussion:** Different surface types of pedicle screws used in spine surgery procedures show different counts of bacteria colonies in-vitro.

## P 070

**Multidisciplinary approach with special consideration of FDG-PET/CT and -MRT for the detection of inflammatory foci in patients with pyogenic spondylodiscitis – a systematic retrospective evaluation of 114 patients**\*N. H. von der Höh<sup>1</sup>, P. Pieroh<sup>2</sup>, C. E. Heyde<sup>3</sup>, T. Kluge<sup>2</sup>, J. Henkelmann<sup>4</sup><sup>1</sup>Universitätsklinikum Leipzig, Klinik für Orthopädie, Unfallchirurgie und Plastische Chirurgie, Leipzig, Deutschland<sup>2</sup>Universitätsklinikum Leipzig, Klinik für Orthopädie, Unfallchirurgie und Plastische Chirurgie, Leipzig, Deutschland<sup>3</sup>Universitätsklinikum Leipzig, Klinik für Orthopädie, Unfallchirurgie und Plastische Chirurgie, Leipzig, Deutschland<sup>4</sup>Universitätsklinikum Leipzig, Klinik und Poliklinik für Diagnostische und Interventionelle Radiologie, Leipzig, Deutschland

**Introduction:** The detection of secondary foci in spondylodiscitis (SD) serves to control infections and, depending on the focus, requires further targeted therapy. There is no unified recommendation on standard diagnostics for secondary focus search in SD. The aim of this study is to analyze the secondary foci

found in the context of an in-clinic search algorithm involving FDG-PET/CT or PET/MRI.

**Material & Methods:** All operated patients between 1/2016 and 10/2020 with microbiologically and/or histologically confirmed spondylodiscitis were included. According to an in-house protocol established since 2016, the focus search is performed by PET/CT or PET/MRI, X-ray chest, urine examination and cardiac echo, among others. In a retrospective review of the data sets, the foci found were determined. According to the foci found, a specialist consultative examination and therapy was carried out according to their specifications. Joint infections were punctured and, if positive, surgically treated.

**Results:** Of a total of 283 patients, 114 fulfilled the criteria of confirmed spondylodiscitis and performed focal search. All patients received chest and urine radiography and FDG-PET examination (103 PET/CT, 11 PET/MRI, 2 patients both). Echocardiography was performed in 83 cases. There were 36 pulmonary (e.g., pneumonic infiltrates, parapleuritic effusions) and in 15 cases gastrointestinal infection findings (e.g., gastroenteritis, colitis) detected. Urinary tract infection was present in 15 cases. Additional spinal infections not directly adjacent were detected in 8 cases. Further infectious foci could be detected endovascularly in the area of vascular prostheses (n=4), cardially (n=7), dentally (n=9) and naso-oropharyngeally (n=4). Pathogens detected in the SD regions were *Staphylococcus aureus* in 11 cases and *E. coli* in 10 cases. Pathologic pathogens were detected in 58 blood cultures: most commonly *Staphylococcus aureus* (n=17), *Staph. epidermidis* (n=11), and *E. coli* (n= 11). Joint endoprosthesis infections were found in 27 cases. Native joint infections were found in 52 patients in a total of 127 locations, most commonly in knees (n=24) and shoulders (n=35). Surgical sanitation of infected joint areas was performed 56 times. In 41 cases, antibiotic therapy was adjusted due to punctures from detected foci.

**Conclusion:** Through the focus search, a high number of multifocal inflammatory foci could be additionally detected, eradicated, and the antibiotic therapy adjusted. In particular, the high number of infected native and artificial joints underscores the valuable diagnostic utility of PET. The comprehensive detection of potential stray foci is a necessary prerequisite for targeted therapy and rapid infection control and can shorten the course of the disease.

## P 071

**The Incidence of spondylodiscitis: What can we expect in the future?**\*V. J. Heck<sup>1</sup>, T. Prasse<sup>1</sup>, K. Klug<sup>2</sup>, J. M. Vinas Rios<sup>3</sup>, S. Oikonomidis<sup>1,4</sup>, B. Himpe<sup>4</sup>, P. Eysel<sup>1</sup>, N. H. von der Höh<sup>5</sup>, M. J. Scheyerer<sup>1</sup><sup>1</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>2</sup>Goethe-Universität, Institut für Psychologie, Frankfurt am Main, Deutschland<sup>3</sup>Sana Klinikum Offenbach, Klinik für Wirbelsäulenorthopädie und rekonstruktive Orthopädie, Offenbach am Main, Deutschland<sup>4</sup>St. Elisabethen-Krankenhaus Frankfurt, Interdisziplinäres Wirbelsäulenzentrum, Frankfurt am Main, Deutschland<sup>5</sup>Universitätsklinikum Leipzig, Klinik für Orthopädie, Unfallchirurgie und Plastische Chirurgie, Leipzig, Deutschland

**Introduction:** The incidence of spondylodiscitis is rising in population. However, despite wider availability of radiological imaging for the broader public and improvement of surgical techniques, spondylodiscitis remains as life-threatening infection with high impact on patients' morbidity rates, reduced quality of life and long hospital stay. The purpose of this study was to provide an overview of expected sex and age – related increase in incidence and to forecast the expected burden of spondylodiscitis on health care systems within the next 40 years.

**Methods:** Comprehensive nationwide data provided by the Federal Statistical Office of Germany was used to quantify spondylodiscitis rates as a function of age and gender. Projections were compared using Poisson regression models as well as an exponential smoothing and autoregressive integrated moving average models on historical incidental rates from 2005 to 2019 in relation to

official population projections from 2020 to 2060, and the most accurate model was chosen.

**Results:** The incidence rate of spondylodiscitis is projected via autoregressive integrated moving average modeling to increase by around 68 % to 19.78 per 100,000 inhabitants [95 % CI 17.66–21.91], leading to a projected total number of 15,765 cases of spondylodiscitis in 2060 [95 % CI 14,074–17,457] with the highest increase modeled in patients over 75 years of age for both men and women. While the incidence rate of cervical spondylodiscitis increases by around 98 % to 2.45 per 100,000 inhabitants [95 % CI 1.82–3.07], the incidence rate of thoracic spondylodiscitis increases by around 147 % to 5.65 per 100,000 inhabitants [95 % CI 5.25–6.07] and the incidence rate of lumbar spondylodiscitis increases by around 41 % to 11.68 per 100,000 inhabitants [95 % CI 9.56–13.79], leading to a projected total number of 1951 [95 % CI 1454–2449] for cervical, 4510 [95 % CI 4181–4838] for thoracic and 9305 [95 % CI 7622–10987] for lumbar spondylodiscitis in 2060.

**Conclusions:** Age-related increase in incidence of spondylodiscitis will place an enormous burden on the German health care system in the future. The estimated increase of spondylodiscitis especially in patients over 75 years emphasizes the need for prevention as well as for proper interdisciplinary treatment strategies for the elderly.

#### P 072

##### Management of lumbar pyogenic spondylodiscitis – survey of German spinal surgeons

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**Introduction:** The incidence of pyogenic spondylodiscitis (PS) is increasing and the disease is associated with considerable morbidity, mortality and healthcare costs. Moreover, there is a paucity of disease-specific treatment guidelines. This cross-sectional survey of German specialist spinal surgeons sought to determine practice patterns and the degree of consensus regarding the conservative and surgical management of lumbar PS (LPS).

**Methods:** An electronic survey assessing provider information, diagnostic and treatment approaches and follow-up care of patients with LPS in response to a variety of clinical vignettes was distributed to members of the German Spine Society. Responses

**Results:** 79 survey responses were included in the analysis. MRI proved the diagnostic imaging modality of choice for 87% of respondents. 100% routinely measure C-reactive protein if LPS is suspected and 70% routinely take blood cultures before therapy commencement. 41% were of the view that surgical biopsy to obtain a microbiological diagnosis should be carried out in all cases of suspected LPS, whereas 23% believe that surgical biopsy should only be carried out when initial empirical antibiotic therapy is ineffective. 38% believe intraspinal empyemas should always be surgically evacuated, irregardless of the degree of spinal cord compression. The median intravenous antibiotic duration is two weeks. The median total duration of the antibiotic therapy (intravenous and oral) is eight weeks. MRI was deemed the preferred imaging modality for follow-up of both conservatively and operatively treated LPS.

**Discussion:** Survey responses demonstrated considerable variation of care in the diagnosis, management and follow-up of LPS among German spine specialists with lack of consensus on key clinical aspects. Further research is required to understand this practice variation and to enhance the evidence base in LPS.

#### P 073

##### A novel anatomic-physiologic high-grade spondylolisthesis model to evaluate L5 nerve stretch injury after spondylolisthesis reduction

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**Introduction:** L5 nerve palsy is a well-known complication following reduction of high-grade spondylolisthesis. While several mechanisms for its occurrence have been proposed, the hypothesis of L5 nerve root strain or displacement secondary to mechanical reduction remains poorly studied. The aim of this cadaveric study is to determine changes in morphologic parameters of the L5 nerve root during simulated intraoperative reduction of high-grade spondylolisthesis.

**Material/Methods:** In this cadaveric study we performed a standard posterior approach to the lumbosacral junction with lumbosacral or lumbopelvic screw fixation in eight fresh-frozen cadavers. Wide decompressions of the spinal canal and L5 nerve roots with complete facetectomies were accomplished with full exposure of the L5 nerve roots. A 100% translational slip was provoked by release of the iliolumbar ligaments and cutting the disc with the attached anterior longitudinal ligament. To evaluate the path of the L5 nerves during reduction maneuvers, metal bars were inserted bilaterally at the inferomedial aspects of the L5 pedicle at a distance of 10 mm from the midpoint of the L5 pedicle screws.

**Results:** There was no measurable change in length of the L5 nerve roots after 50% and 100% reduction of spondylolisthesis.

**Discussion:** Mechanical strain or displacement during reduction is an unlikely cause of L5 nerve root injury. Further anatomical or physiological studies are necessary to explore alternative mechanisms of L5 nerve palsy in the setting of high-grade spondylolisthesis correction, and surgeons should favor extensive surgical decompression of the L5 nerve roots when feasible.

#### P 074

##### Clinical application of neuronavigation for lateral instrumentation of the thoracolumbar spine

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**Introduction:** The potential of computed tomography (CT)-based neuronavigation in spinal surgery reaches beyond pedicle screw placement. In this study, neuronavigation for lateral instrumentation of the thoracolumbar spine was analyzed.

**Methods:** Patients scheduled for lateral instrumentation were prospectively included. For neuronavigation, a registration array was attached to the pelvis and a computed tomography scan was acquired intraoperatively. A control CT-scan was routinely performed after final placement of the implants instead of conventional 2-dimensional X-ray scans.

**Results:** 100 patients were enrolled from April to October 2021 with a median of 1 (1-4) level being instrumented. Indications for surgery were trauma (39%), spinal infection (31%), primary and secondary tumors of the spine (17%) and degenerative spine disease (13%). Duration of surgery after the first CT-scan was 96+/-38 (30-186) minutes. In total, 124 cages were implanted (69 expandable cages for vertebral body replacement (55.6%) and 55 cages for interbody fusion (44.4%)). Neuronavigation was impaired in four cases (4.0%) (two cases of major inaccuracy due to reference array mispositioning, one case of software issues, one case of anatomical issues). Intraoperative CT issues required conventional X-ray-scans for implant positioning control in two cases (2.0%). Intraoperative cage repositioning was performed in 16 cases (16%) – postoperative cage-revision in one case (1.0%). The intraoperative mental load was rated on a scale from 0 to 150 (maximal effort) by surgeons, showing a moderate effort (median 30 (10-120)). Evaluations confirmed overall high satisfaction regarding installation of the registration array, handling of the system, reliability, and patient safety.

**Conclusion:** CT-based neuronavigation in lateral spinal instrumentation – compared to free-hand or X-ray based instrumentation – provides highly accurate surgery planning and implant placement as well as potentially reduced radiation exposure and surgery duration.

## P 075

**The one-stop-shop approach – navigating lumbar 360 degree instrumentation in single positioning**

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**Background:** Neuronavigation for pedicle screw placement is routinely performed. Neuronavigation for lateral instrumentation is also an upcoming approach. We started to perform navigated dorsal and lateral instrumentation of the lumbar spine in a single operation and positioning.

**Methods:** Patients with 1- or 2-level discitis scheduled for dorsal and lateral instrumentation were prospectively enrolled and surgeons' evaluations were acquired. Patients were positioned semi-prone in 45 degree fashion to enable both pedicle screw placement and lateral interbody fusion (LLIF). For navigation, a registration array was attached to the pelvis or spinal process and intraoperative computed tomography (ioCT) scans were acquired for registration and control of screw and cage positioning.

**Results:** We included 10 patients with 1- or 2-level discitis. The mean±standard deviation body-mass index was 28.5±6.0 with a median (range) ASA score of 2.5 (1-3). We placed 46 pedicle screws with an intraoperative revision rate of 13.0%, primarily based on a navigation error during one surgery leading to revision of 4 screws. LLIF was performed on 13 levels with an intraoperative revision in 1 patient (7.7%). Mean duration of surgery was 127.4±42.0 min with a mean blood loss of 410±354 ml without intra- or postoperative complications. The new positioning and orientation for instrumentation was positively rated with an overall median of 9 (range 3-10; [scale min-max 1-10]) and a median mental load of 20 (range 0-100; [scale max-min 150-0]). A learning curve was measurable by the decrease of mental load.

**Conclusion:** Navigated lumbar dorsal and lateral instrumentation in a single operation and positioning is feasible and safe. It enables to accelerate 360° instrumentation of patients and shows high acceptance and learning curves even in a high-volume spine center. Compared to standard LLIF technique, anatomical orientation and physical burden seem to be advantageous at least in a subjective manner.

## P 076

**Foraminal stenosis at L5/S1 – radiographic risk factors for treatment failure**

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**Background:** Surgical treatment of neuroforaminal stenosis (LFS) at the lumbosacral junction poses a challenge to many spine surgeons as the surgical field is limited by the iliac crest and arthritic facets. Decompression is impeded by wide pedicles and the laterally extending interpedicular space. Microscopic-assisted foraminotomy using the Wiltse approach is the current gold standard with only minimal violation of the lateral facet. The aim of this study was to identify radiologic parameters for therapeutic failure.

**Methods:** After obtaining approval from the institutional ethics committee, a single-center retrospective analysis was conducted to assess the correlation between the radiologic degree of neuroforaminal stenosis and surgical outcome. The degree of nerve root compression was evaluated according to Lee's classification after dividing the lumbar neuroforamen into 3 zones: entry zone, midzone and exit zone.

**Results:** 131 patients underwent a lateral foraminotomy and or disc surgery at the level L5/S1. Of those, 77 patients were male (58.8%) and the mean age was 58.3 ± 13.3 years (22 – 83 years). Twenty-eight patients (21.4%) underwent revision surgery within 1-year follow-up period. The main radiologic risk factor for treatment failure was a preoperative grade II or III foraminal stenosis of the entry zone (p=0.005).

**Conclusion:** Precise morphologic evaluation of the radiographic images alongside with clinical correlation is the key how to

achieve good clinical outcome. Neuroforaminal stenosis must be assessed at all three zones to adequately select the optimal surgical approach. High degree (grade II and III) neuroforaminal stenosis at the entry zone is a significant negative predictor following minimal invasive lateral foraminotomy.

## P 077

**Changes in the management of myelopathy during the COVID-19 pandemic in a nationwide hospital network in Germany**

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**Introduction:** The Covid-19 pandemic has negatively impacted the management of spinal pathologies. Since, so far, the pandemic's effects specifically on the management of myelopathy in Germany have not been examined, we aim to do so in this analysis.

**Methods:** We used administrative data from a nationwide Network of 76 hospitals for this retrospective analysis and compared the first 5 pandemic waves (Jan 1, 2020 – May 17, 2022) to corresponding periods from the last year prior to the pandemic (2019). We included all patients hospitalized with the main diagnosis "myelopathy" (ICD-10-Codes: M47.11-15, G95.2, G99.2) and examined baseline characteristics and rates of different treatment types and in-hospital mortality.

**Results:** We included 4,167 cases with myelopathy: 2,001 hospitalized during the pandemic, and 2,166 in 2019. Compared to pre-pandemic levels, the mean daily admissions for myelopathy decreased only in wave 1 (from 2.8 auf 1.7; p<0.01), while no changes in admissions were registered in any of the later waves. There were no alterations in patient age (range: 64.5-66.1 years), distribution of sex (female, range: 39.3%-50.4%), or rates of comorbidities, measured by the Elixhauser Comorbidity Index (range: 4.3-6.5). In contrast, we observed significant changes in the analysis of treatment modalities. Except in wave 1, there was a significant increase in rates of spinal decompression procedures throughout the pandemic, from a range of 43.3-47.0% before the pandemic to 55.6%-62.5% (p<0.01). Also, compared to pre-pandemic levels, the rates of disc hernia resections increased during waves 4 and 5 from a range of 29.8-30.4% to 37.1-41.1% (p<0.01). Furthermore, the rates of spinal fusion procedures increased in waves 3, 4, and 5 from a range of 32.7-40.5% to 45.0-50.4% (p<0.01). No changes were observed throughout the pandemic for rates of kyphoplasty (0.2-1.0%), transfer to intensive care unit (22.9-30.7%), and in-hospital mortality (1.1-2.7%).

**Discussion:** We present the largest analysis, to date, on the effects of the COVID-19 pandemic on the management of myelopathy in Germany. Our findings suggest that, in subjects with myelopathy, the pandemic did not lead to a selection for older or sicker patients. The fact that hospital admissions for myelopathy dropped off only during the wave 1 suggests a certain normalization over time. This is why it is worth discussing why rates of surgery increased in later phases of the pandemic, both for fusion and non-fusion procedures.

#### P 078

##### Impact of sagittal alignment on the outcome of patients with spondylotic myelopathy after surgical decompression and instrumentation – a long term follow up study

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**Objective:** The aim of this study was to evaluate the influence of sagittal alignment parameters on the long-term outcome of patients with cervical spondylotic myelopathy (CSM) after surgical decompression and instrumentation.

**Methods:** In this study patients with cervical spondylotic myelopathy and surgical treatment between 2010 and 2018 were retrospectively analyzed. Data of all analyzed patients were retrieved from spine database of our institution. Sagittal alignment parameters like Cobb's angle C2-C7, sagittal vertical axis (SVA) C2-C7, T1 slope, neck tilt and thoracic inlet angle (TIA) as well as the mJOA scores were measured preoperatively and at the end of follow up. The effect of sagittal alignment parameters was compared between patients with physiological and nonphysiological parameters. Finally, the impact of sagittal alignment parameters on the extent of improvement of the mJOA scores was assessed.

**Results:** We identified 155 patients with CSM presenting with a pathologic mJOA score who underwent surgical decompression, surgical instrumentation from ventral, dorsal or dorsoventral. Due to the preoperative mJOA score, 67 patients (42,9%) improved, 87 patients (55,8%) were unchanged and one (6%) patient deteriorated at the end of follow up.

In 128 cases (82,6%) unphysiological sagittal alignment parameters were detected preoperatively. No significant differences were found for all five evaluated postoperative sagittal alignment parameters between patients with physiological and unphysiological parameters vs. improvement and non-improvement mJOA score. There were also no significant differences described for extent of postoperative correction of sagittal alignment parameters and the improvement and non-improvement mJOA score. However significant differences were found for physiological preoperative sagittal alignment parameter SVA ( $p < 0,042$ ) and neck tilt ( $p < 0,043$ ) and the extent of improvement after surgery. Mean follow up was 15.4 months  $\pm$  25.

**Conclusion:** Postoperative improvement of patients with CMS and physiologic preoperative sagittal alignment parameters reflects the importance of early surgical treatment.

#### P 079

##### Evaluating a paradigm shift from anterior decompression and fusion to muscle-preserving selective laminectomy – a single-center study of degenerative cervical myelopathy

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**Objective:** Muscle-preserving selective laminectomy (MSL) is an alternative to conventional decompression surgery in patients with degenerative cervical myelopathy (DCM). It is less invasive, preserves the extensor musculature, and maintains the range of motion of the cervical spine. Therefore, at our institution, the preferred treatment for DCM has changed from anterior decompression and fusion (ADF): anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF), towards MSL. Our aim was to evaluate surgical outcomes before and after this paradigm shift with patient-reported outcome measures (PROMs), complications, reoperations and cost-effectiveness.

**Methods:** This study was a retrospective register-based cohort study. All patients with subaxial DCM who underwent ADF or MSL at our institution from 2008 to 2019 were reviewed. Using analysis of covariance (ANCOVA), changes in PROMs from baseline to the 2-year follow-up were compared between the two groups, adjusting for clinicodemographic parameters, baseline PROMs, number of decompressed levels, and magnetic resonance imaging (MRI) measurements (C2-7 Cobb, C2-7 SVA, modified K-line interval). The PROMs, including the European Myelopathy Score (EMS), the Neck Disability Index (NDI), and the European Quality of Life-5 Dimension Questionnaire (EQ-5D), were collected from the national Swedish Spine Register. Complications, reoperations, and in-hospital treatment costs were also compared between the two groups.

**Results:** Ninety patients (mean age 60.7 years, 51 men [57%]) were included in the ADF group, and 63 patients (mean age 68.8 years, 41 men [65%]) in the MSL group. The ADF and MSL groups presented similar PROMs at baseline. The preoperative MRIs presented similar C2-7 Cobb angles (10.7 [ADF] versus 14.1 [MSL],  $p = 0.12$ ) and modified K-line intervals (4.08 versus 4.88,  $p = 0.07$ ), but different C2-7 SVA values (16.2 versus 19.3,  $p = 0.04$ ). The comparison of ANCOVA-adjusted mean changes in PROMs from baseline to the 2-year follow-up presented no significant differences between the groups (EMS:  $p = 0.901$ , NDI:  $p = 0.639$ , EQ-5D: 0.378, EQ-5D health:  $p = 0.418$ ). The overall complication rate was twice as high in the ADF group (22.2% versus 9.5%,  $p = 0.049$ ), while the reoperation rate was comparable (16.7% versus 7.9%,  $p = 0.146$ ). The average in-hospital treatment cost per patient was 6,870 USD for MSL, 7,737 USD for ACDF, and 14,953 USD for ACCF.

**Conclusions:** MSL provides similar PROMs after 2 years, a significantly lower complication rate, and better cost-effectiveness compared with ADF.

#### P 080

ePoster withdrawn

#### P 081

##### Semi-elastic image fusion based pedicle screw planning in upper cervical spine trauma

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**Introduction:** Screw placement in the upper cervical spine can be particularly challenging due to the close relationship between bony and neurovascular structures. As there is a high risk of compromising these structures and thus to protect and conserve the delicate anatomy, preoperative screw planning and especially navigated placement offers a higher accuracy based on 3D data. However, due to varying patient position pre- and intraoperatively and higher flexibility of the cervical spine, image co-registration and thereby transferring preplanned screws applying a rigid image fusion approach is limited by potential inaccuracies. A semi-elastic image fusion approach might overcome those limitations by not only using translations and rotations but also deformations to more precisely compensate for different spatial alignment of the spine in preoperative and intraoperative data.

**Materials/Methods:** A retrospective single-center study of eight patients who underwent instrumented fusion for C2 fractures was

performed. In all patients, screw trajectories were preoperatively defined within the preoperative data sets serving as landmarks for accuracy analysis. Monosegmental rigid fusion (Elements Image Fusion) and semi-elastic fusion (Elements Curvature Correction Spine, BrainLAB AG, Munich, Germany) was performed in all patients. For both fusion types the Euclidian distance between transferred landmarks (tip and entry) and reference landmarks as well as angular deviation between planned and final trajectory was calculated to quantify the accuracy of the different procedures.

**Results:** In two out of eight patients, neither rigid nor semi-elastic fusion lead to sufficient registration results due to severely dispersed fractures. In the remaining six patients the mean Euclidean distance for rigid and semi-elastic fusion in relation to the ground truth was  $1.39\text{mm} \pm 0.77\text{mm}$  vs.  $0.62\text{mm} \pm 0.46\text{mm}$  (tip),  $1.87\text{mm} \pm 1.19\text{mm}$  vs.  $0.56\text{mm} \pm 0.27\text{mm}$  (entry), the mean angular deviation was  $3.48^\circ \pm 2.73^\circ$  vs.  $1.27^\circ \pm 1.43^\circ$ , showing significant differences ( $p < 0.01$ ) between registration accuracy in rigid and semi-elastic approach.

**Discussion:** Semi-elastic image fusion demonstrated a significantly higher registration accuracy measured at the level of the screw tip, screw entry point and angulation. Thus, semi-elastic fusion approaches allow for a more precise mapping of preoperatively planned screws to intraoperatively acquired data overcoming some limitations of only standard monosegmental rigid image fusion. Nevertheless, within the recent implementation, semi-elastic image fusion remains still limited in some cases as intrinsic restrictions might inhibit to strong image deformations needed in case of e.g. severely dispersed fractures.

#### P 082

##### Cavernous malformations and hemangioblastomas of the spinal cord show distinct differences in clinical course – a retrospective single-center analysis of 112 patients

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**Objective:** Cavernous malformations (CM) and hemangioblastomas (HB) of the spinal cord show distinct differences in initial presentation and neurological course after surgical treatment. The aim of our study was to analyze the clinical differences between vascular-tumor-like lesion of the spinal cord in the perioperative situation.

**Methods:** We performed a retrospective analysis of patients undergoing surgical treatment of lesions of the spinal cord at our department in the period from 1984 to 2015. Patients were screened for CM and HB as primary inclusion criteria. General patient information, surgical data and disease-specific data were collected from the records. Cooper Epstein scores for clinical symptoms were evaluated preoperatively, at discharge and at 6 months follow-up. An ethics vote has been requested but is pending.

**Results:** A total of 112 patient fulfilling the inclusion criteria were identified, of which 46 were diagnosed with CM and 66 with HB. The main site of manifestation was the cervical as well as the thoracic spinal cord. Patients with CM showed preoperatively neurological deterioration compared with HB ( $p < 0.05$ ); fittingly, the duration of diagnosis was much longer in HB. Resection was complete in 96.8% of all CM and 90.0% of HB. At 6 months follow-up, patients with HB more often showed persisting neurologic impaired for the upper extremity compared with CM patients ( $p < 0.001$ ).

**Conclusion:** CM and HA of the spinal cord are vascular- tumor-like lesions with significantly differences in the initial neurological presentation. Complete surgical resection can be achieved in the majority of both entities, but postoperative neurological deterioration is significantly more prevalent in HA.

#### P 083

##### A new therapeutic regime for neuromuscular scoliosis depending on underlying disease and correction potential

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The decision to instrument to L5 or ilium, in cases of neuromuscular scoliosis, is usually based on radiologic factors, including pelvic obliquity  $>15^\circ$ , apex of curvature  $<L3$ , and Cobb angle  $>60^\circ$ . This ignores the underlying disease. Based on the fact that spastic or flaccid paralysis behaves quite differently, we have changed this and will discuss the opportunities and the challenges of shorter instrumentation. From 2014 to 2021, the senior author operated on 127 neuromuscular scolioses, of which 109 involved primary fusion. Of the patients with spastic paralysis, 55% were instrumented to the ilium compared to only 20% of those with degenerative muscle disease. The 61 patients with degenerative muscle disease (Duchenne's disease, SMA, etc.) had a mean preoperative curvature of  $68^\circ$ , pelvic obliquity of  $16^\circ$ , and truncal shift of  $20^\circ$ . According to the above mentioned criteria, 69% should have been instrumented to the pelvis instead of 20%.

Only 21 patients were instrumented to the pelvis. Of these, 11 patients had spasticity due to infantile cerebral palsy. These had a mean preop. curvature of  $89^\circ$ , a pelvic obliquity of  $21^\circ$ , and a truncal shift of  $25^\circ$ . The main factor for our decision in all patients was the correction potential of the truncal shift (deviation of the plumb line from T1/ilium to the perpendicular on pelvis) as well as the pelvic obliquity in the supine and traction radiographs.

In the L5 group we achieved an average correction of the main curvature to  $24^\circ$  and a correction of the pelvic obliquity and truncal shift to  $8^\circ$  each. The operation time was 200min in the L5 and 271min in the ilium group. In the subgroup of those who should have been instrumented to the pelvis, according to old criteria, there was no significant difference in postoperative correction, perpendicular and pelvic obliquity. Subsequent extension to the pelvis was needed in 2 ICP patients. Due to the long lever arm, small vertebrae, and osteopenia in SMA, we found increased rate of screw loosening in the L5 group (23% in 2 years), with only 16% requiring revision. Therefore, since 2019, such patients increasingly received an additional ventral fusion with OLIF over 2-3 segments. (Operation time: 49min, blood loss: 92ml). Since then no further screw loosening has been detected in such cases.

**Conclusion:** the decision on instrumentation length should not be made based on radiological parameters alone, but should take flexibility and underlying disease into consideration. With flexible curves, shorter instrumentation may be sufficient.

Increased rate of screw loosening, can be effectively prevented by an OLIF over 2-3 segments without significantly increasing the burden on the children.

#### P 084

##### Surgical treatment of adolescent idiopathic scoliosis with a dynamic deformity correction system – a 12-month follow-up

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**Introduction:** Adolescent idiopathic scoliosis (AIS) represents a three-dimensional growth disorder in the third growth phase. Thoracic curves with a COBB angle of  $50^\circ$ , lumbar  $40^\circ$ , and above are indicated for corrective spondylodesis, which is a fusion procedure. In recent years, growth-guiding implants with different approaches to curve correction have been developed. The aim of the following study is to present the 12-month correction results of the cohort of patients treated with the dynamic deformity correction system at two centers in comparison to other growth-guiding systems.

**Material & Methods:** The system used is designed as a "posterior dynamic device" that allows curve correction and possible growth

guidance via a "ratchet mechanism". Precondition for treatment: AIS, curve type Lenke 1/5, COBB angle- bending  $<30^\circ$ , COBB angle total curve  $<60^\circ$ . The following parameters are included in the descriptive analysis, which is based on the observation of radiological imaging at different measurement times: COBB angle preoperatively (t0), COBB angle postoperatively (t1-t5). The statistical program SPSS 27.0 (IBM) was used for statistical analysis. Quantitative characteristics were described by average, standard deviation, minimum, maximum, and number of available observations. For the qualitative characteristics, the absolute and percentage frequency were given.

**Results:** From 4/2018 – 10/2020, 36 patients\* were treated with the "posterior dynamic device" at both study centers.

The collective is composed of 25 (69.4%) female and 11 (30.6%) male patients, with an average age of 15.1 years. Lenke 1 curve type was present in 21 cases, and Lenke 5 in 11 cases. The average preoperative thoracic COBB angle (Lenke 1) was  $43.32^\circ$ . The lumbar preoperative COBB angle (Lenke 5) was  $42.91^\circ$ . Over the longitudinal follow-up of 12 months, the COBB angle of the thoracic curve (Lenke 1) was corrected to an average of  $23.97^\circ$ , and the COBB angle in the lumbar curves (Lenke 5) to an average  $10.63^\circ$ . Curves type Lenke 1 as well as 5 show significant changes of the COBB angle over single measurement time points in the pairwise comparisons to the initial angle (Lenke 1: t0-t4  $<0.00$ , Lenke 5: t0-t4  $<0.001$ ). A total of 4 complications leading to revision occurred within the first 12 months.

**Discussion:** Straightening of AIS using growth guidance has been a surgical treatment alternative to fusion procedures for more than a decade. The postoperative results of the presented series reveals a statistically proven improvement in the the preoperatively measured COBB angle over different measurement time points in a 12M follow-up for Lenke 1 and 5. The biomechanical stress on the "growing with" system is immense. Whether the curve correction will be permanent must be clarified in long-term studies.

#### P 085

##### Prospective register study of adolescent idiopathic scoliosis with 1- and 2-year follow-up

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**Introduction:** Studies on surgical treatment of adolescent idiopathic scoliosis (AIS) predominantly focus on radiological parameters, whereas patient satisfaction measures (PROMs) are rarely reported.

**Material:** Prospective data collection of a scoliosis center within a multicenter study of the German Spine Society. AIS who underwent surgery from 05/2019 to 03/2021 and 12 and 24 months follow-up (FU) were included. Inclusion criteria: age 11-17 years, standing x-rays of whole spine in 2 planes before surgery and at FU, preop bending films. Clinical data, radiographic parameters and PROMs (SRS-30 questionnaire) were assessed. Parameters were given as mean $\pm$ SD. Differences between preop vs. FU were analyzed by student's t-test (significance  $\alpha=0.05$ ) and Pearson's correlations.

**Results:** A total of 51 patients (f:46, m:5) were successfully included. 100% had complete x-rays, 88% SRS-30 questionnaires. Mean age was  $15.0\pm 1.4$  years, mean BMI  $20.7\pm 3.7$  kg/m<sup>2</sup>, mean FU was  $18.5\pm 6.7$  months (49% with 2-year FU). Distribution of Lenke types: 1=60%, 2=6%, 3=12%, 4=2%, 5=3%, 6=8%. Mean fusion length was  $9.2\pm 2.3$  segments, mean implant density  $93\pm 9\%$ , mean surgery time  $215\pm 71$  min with a mean blood loss of  $504\pm 360$  ml. Mean major curve was  $64\pm 14^\circ$  preop, second major curve was  $46\pm 12^\circ$  and was corrected by  $68\pm 11\%$  and  $57\pm 21\%$  at FU, respectively ( $p<0.05$ ). The mean thoracic rib hump and lumbar hump decreased significantly by  $-8.4\pm 6.8^\circ$  and  $-7.4\pm 9.1^\circ$ , respectively ( $p<0.5$ ). The high thoracic rib hump was almost unchanged,  $-0.2\pm 2.9^\circ$  ( $p=0.7$ ). Significant change in LIV-tilt from  $24.5\pm 6.7^\circ$  to  $6.5\pm 4.3^\circ$  ( $p<0.05$ ). Non-significant correction in thoracic kyphosis by an average of  $-0.1\pm 13.1^\circ$  ( $p=0.9$ ), lumbar lordosis (LL)  $1.5\pm 10.1^\circ$  ( $p=0.3$ ), C7 lot deviation  $-0.6\pm 13.5^\circ$  ( $p=0.8$ ), clavicle angle  $-0.3\pm 3^\circ$  ( $p=0.5$ ) and spinopelvic parameters ( $p\geq 0.2$ ). Complication rate n=1: postoperative palsy with complete recovery.

Average SRS-30 total score was  $3.6\pm 0.5$  before surgery,  $4.3\pm 0.3$  at FU (diff.  $0.7\pm 0.5$ ,  $p<0.05$ , Fig 1). Significant improvement of subcategories: pain by an average of  $0.8\pm 0.7$ , self-image  $1.0\pm 1.0$ , satisfaction with treatment  $1.3\pm 0.8$  ( $p<0.05$ ), no significant improvement ( $0.2\pm 0.8$ ) for function/activity ( $p=0.2$ ). Self-image improved in 66% of patients. Moderate-strong correlation: the lower the surgery time and amount of fused segments ( $r=-0.4$ ;  $p<0.05$ ) and the greater correction of LIV and LL at FU ( $r>0.4$ ,  $p<0.05$ ), the better was the SRS-30 total score. Only weak correlation to correction of major curves ( $r<0.1$ ).

**Discussion:** In conclusion, the results of this study demonstrate good surgical correction and significant improvement of most PROMs. Unlike a common assumption, curve correction did not correlate with patient's satisfaction.

Fig. 1

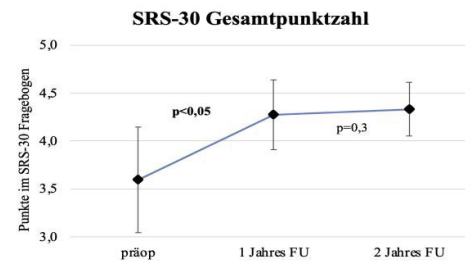


Abb. 1.: SRS-30 Gesamtsumme zum Zeitpunkt der einzelnen Untersuchungen. FU=follow-up. P-Wert mit Signifikanzniveau  $\alpha=0.05$ . Fehlerindikatoren markieren die jeweilige Standardabweichung.

#### P 086

##### Is the anterior approach still superior to posterior correction in AIS regarding fusion levels and kyphosis, when modern posterior systems are used for AIS correction?

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**Introduction:** In former days the sparing of fusion levels and better kyphosis restoration were arguments for anterior correction. Most studies compared dorsal systems which are no longer used nowadays as CD or Harrington. The aim of our study is to compare anterior thoracic and lumbar corrections to those achieved with modern posterior pedicle screw systems including vertebral derotation techniques. Thus, similar Lenke IA or V curves were selected and curves that cannot be corrected with both systems were excluded.

**Methods:** This is a retrospective single-center, single surgeon study. Two groups have been identified. A thoracic group (n=56) of Lenke I AIS patients with preoperative Cobb angle ranging from 45-65 degrees and the lowest instrumented vertebra (LIV) being Th11 or Th12; and a lumbar group (n=42) of Lenke V patients with preoperative Cobb angle ranging from 40-60 degrees and the LIV being L3. Of the thoracic cases 18 had a ventral and 38 a dorsal approach. In the lumbar group we had 14 ventral and 28 dorsal cases. Demographic data, pre- & postoperative radiographic measures for coronal and sagittal planes have been identified for both groups.

##### Results: Thoracic Group

The mean preoperative Cobb angle of the major curve was  $52^\circ$  ( $\pm 6.6$ ) in the ventral group and  $53^\circ$  ( $\pm 5.9$ ) in the dorsal group; and was corrected to  $17^\circ$  ( $\pm 8.0$ ) and  $16^\circ$  ( $\pm 5.3$ ) in the ventral and dorsal groups respectively. The postoperative correction (POC) was  $68 \pm 13.4 \%$  in the ventral and  $72 \pm 10.5 \%$  in the dorsal group. The postoperative change in thoracic kyphosis was  $+4$  and  $+5$  degrees in the ventral and dorsal groups respectively. The mean length of fusion was  $7$  ( $\pm 1.3$ ) segments in the ventral group, and  $8$  ( $\pm 1.0$ ) segments in the dorsal group. There was no difference in LIV in both groups.

##### Lumbar Group

The mean preoperative Cobb angle of the major curve was  $48^\circ$  ( $\pm 6.1$ ) in the ventral group and  $48^\circ$  ( $\pm 5.9$ ) in the dorsal group; and was corrected to  $11^\circ$  ( $\pm 8.1$ ) and  $13^\circ$  ( $\pm 5.0$ ) degrees in the



ventral and dorsal groups respectively. The postoperative correction (POC) was 75 +/- 18.3 % in the ventral group and 72 +/- 8.5 % in the dorsal group. The postoperative change in lumbar lordosis was -0.7 and -4 degrees in the ventral and dorsal groups respectively. The postoperative change in thoracic kyphosis was +2 and +3 degrees in the ventral and dorsal groups respectively. The mean length of fusion was 6 (+/- 1.7) segments in the ventral group, and 6 (+/- 1.7) segments in the dorsal group.

**Conclusion:** With modern implants and derotation techniques, the posterior approach can obtain similar results regarding Cobb angle reduction, postoperative correction (POC) and thoracic kyphosis with similar fusion length as the anterior approach, when correcting thoracic and lumbar curves. The effect on more severe and stiffer curves, adjacent curves, long-term radiological, and clinical outcomes, might be subject to further studies.

#### P 087

##### Prospective study of the ergonomics using a robotic exoscope with a head-mounted display

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**Introduction:** Conventional microscopes have been an integral part of modern neurosurgery for decades. Nevertheless, due to the largely unchanged design with fixed eyepieces attached to the device, some disadvantages in terms of posture and ergonomics have been claimed. Monitor-based exoscopes could solve this problem and thereby lead to less work-related sick leave for surgeons. The aim of this study was to assess the ergonomics, usability, and neurosurgeon's comfort of a novel three-dimensional head-mounted display-based exoscope in a standardized setting.

**Material/Methods:** A total of 34 neurosurgeons naïve to the device participated in a workshop on the exoscope, which features a head-mounted display and a head gesture-triggered control panel. After completion of a custom-made 10-step microsurgical exercise, a questionnaire was answered with regard to image quality and comfort. Participants' posture and performance during the procedure were analyzed using video motion analysis software.

**Results:** 34 participants with a median neurosurgical experience of 6 years were included. The median time to complete the exercise was 12 minutes (inter-quartile range [IqR] 9.4, 15.0). Significantly less time was needed for steps 6-10 compared to steps 1-5, especially in younger participants ( $p=0.005$ ) and those with video game experience ( $p=0.03$ ). Overall, participants reported no major difficulties using the exoscope, with median satisfaction at 80% for the device in general and 82% for image quality. 88% of the participants would feel safe to use the RoboticScope in the OR with technical assistance. The median coronal displacement of the upper body as well as the head displacement from the neutral axis was 0° [IqR -3, 5 and 0, 2; respectively]. Participants with less microsurgical experience showed less head and body displacement during the exercise ( $p=0.01$ ).

**Discussion:** The robotic exoscope showed high participant approval in terms of ease of use and image quality. Using the microsurgical training tool, we were able to map a steep learning curve with sufficient learnability of key commands. The exoscope was also characterized by an ergonomically favorable posture and could become an alternative to conventional microscopes due to the potentially higher comfort for the surgeon.

#### P 088

##### An implanted spinal window chamber allows for chronic longitudinal *in vivo* microscopy following experimental Spinal Cord Injury in the mouse

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**Objective:** Longitudinal *in vivo* microscopy allows for a direct real-time insight into pathophysiological processes in the living organism. After experimental Spinal Cord Injury (SCI) it can contribute to a deeper understanding of pathophysiological processes and potential therapeutic approaches. The implantation of a spinal window chamber enables longitudinal *in vivo* imaging of the spinal cord without the necessity for repeated surgery. With this study, we show the modification of an established spinal window chamber for chronic longitudinal *in vivo* imaging after experimental SCI in the mouse.

**Methods:** Adult C57BL/6J mice (m/f, n=8) underwent low-thoracic (Th11/12) clip-compression SCI using a modified aneurysm clip (5g, 60s) or sham-injury (two-level-laminectomy), followed by the implantation of a spinal window chamber for later *in vivo* microscopy. Perioperative antibiotic therapy with amoxicillin and postoperative pain medication with buprenorphine was applied. *In vivo* white light and fluorescence microscopy to image blood flow (FITC) and inflammation (Rhodamine-dextran) was performed at postoperative days 1, 3, 7, 14 and 28. Additionally, neurobehavioral assessment (Catwalk® automated gait analysis and Basso Mouse Scale) was performed at the given time points. Neurobehavioral analysis was compared to specimens (C57BL/6J mice, m/f, n=12) with SCI or sham-injury without spinal window chamber implantation. Histological analysis for tissue integrity assessment (Luxol-Fast-Blue + H&E) was performed after 7 and 28 days follow-up. Animal experimental permission was granted (G031417).

**Results:** Chronic longitudinal *in vivo* white light and fluorescence microscopy was possible up to 28 days postoperatively after both SCI and sham injury. Only mild inflammation was observed in individual specimens at early timepoints (up to 7d). Specimens with an implanted spinal window chamber did not show any differences in automated gait analysis (Catwalk®), Basso Mouse Scale, postoperative body weight development or histologically assessed spinal cord integrity compared with specimens which received the same surgery without spinal window chamber implantation.

**Conclusions:** The implantation of a spinal window chamber after clip compression SCI in the mouse is feasible and allows for longitudinal *in vivo* imaging up to the chronic injury phase without modifying neurological function or spinal cord integrity compared to specimens without chamber implantation. To achieve more detailed *in vivo* imaging at a greater depth, longitudinal two-photon microscopy can be integrated in the setup.

#### P 089

##### Abdominal aortic calcification as a screening tool for osteoporosis in spine surgery

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**Background:** The aim of this study was to determine whether the presence of abdominal aortic calcification (AAC) can predict patient bone status, represented by volumetric bone mineral density (vBMD) assessed with quantitative computed tomography (QCT).

**Methods:** Patients undergoing lumbar fusion surgery at a tertiary care center between 2014 and 2021 were retrospectively reviewed. A semi-quantitative measurement method for AAC (AAC 4, AAC 8 and AAC 24) was performed using preoperative lumbar radiographs. QCT measurements were made for L1 and L2 and were averaged. Patients were divided into two groups depending on whether AAC was present.

A one-way analysis of covariance was conducted to adjust for age. The Spearman correlation coefficient was determined for vBMD and the AAC measurements. A multiple linear regression model was used to test if age, sex, BMI and presence of AAC could predict the vBMD. A receiver operating characteristic (ROC) analysis was conducted to determine the specificity and sensitivity of AAC for predicting osteoporosis.

**Results:** 267 patients (55.8% female) with a median age of 65.1 years and BMI of 29.8 kg/m<sup>2</sup> were analyzed. Overall, 59.6% of patients had AAC. The group comparison showed that vBMD was significantly lower in patients with the presence of AAC (97.8 mg/cm<sup>3</sup> vs. 121.5 mg/cm<sup>3</sup>). Age ( $\beta$ =-0.367;  $p$ <0.001) and presence of AAC ( $\beta$ =-0.151;  $p$ =0.018) significantly predict vBMD (corrected  $R^2$ =0.196) as independent variables. Osteoporosis could be discriminated using AAC 4, 8 and 24 (cut off value 0.5) with a sensitivity of 70.1% and a specificity of 60.2% with an AUC of 0.674, 0.673 and 0.672, respectively.

**Conclusion:** The presence of calcification of the abdominal aorta may identify patients at risk for impaired bone status. Preoperative evaluation of standard lumbar radiographs could be used as a potential diagnostic tool in assessing bone status and surgical risk management.

#### P 090

##### Ergonomics and work-related complaints in spine surgeons – a survey in DWG members

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**Introduction:** Operations on the spine require a high level of concentration, manual skills, as well as physical and mental strength. However, one's own health can also be negatively influenced by the working conditions in the operating room. The prevalence of musculoskeletal disorders in surgeons is estimated at around 20-70% with possible consequences for their own careers, surgical skills and thus the quality of patient care. Hardly anything is known about work-related complaints among spinal surgeons.

**Material/Method:** A link to the survey website (SurveyMonkey) was emailed to DWG members. All answers were checked for completeness, incomplete data sets were not considered.

**Results:** 163 data sets were evaluated. The participants had a mean age of 49±8 years, were male in 88%, 38% had 10-20 years of work experience and 39% had 21-30 years of work experience. The annual operative caseload was given as 100-200 for 40% of the colleagues and 201-300 for 25%, rarely less than 100 (18%) or more than 300 (17%) operations/year were performed. 77% of the participants stated that they had physical complaints related to their surgical work in the past year. This was tension in 76% and pain in 71%, sleep disturbances were reported in 25%, weakness/muscular fatigue in 21%, sensory symptoms in 17%. The complaints were mainly localized (68%) in the neck-shoulder area and primarily occurred with long instrumentations (51%). In 24%, no connection was seen with the type of intervention, in 17% the complaints occurred primarily during microsurgical operations. 29% of the participants had to seek medical help because of their problems, and 11% even had an operation performed. 9% each had to take sick leave or reduce their caseload. Interestingly, 74% of the colleagues have not yet made any changes to their way of working as a result of their complaints, but could imagine performing regular microbreaks (44%), using more ergonomic instruments (42%), or conducting an ergonomic training program (36%) in the future. 90% of the survey participants believe that too little attention is paid to work-related health and ergonomics in their everyday life. They primarily saw themselves (79%) and the employer (55%) as being responsible to change this.

**Discussion:** Work-related complaints are common among spine surgeons and have a clear impact on their everyday work. So far too little attention has been paid to the topic. However, the need for a future adjustment of the way of working, e.g. taking into account ergonomic aspects, is very high.

#### P 091

##### Dorsal Instrumentation – dramatic projected increase in surgical procedures over the next 40 years

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**Introduction:** The rates of dorsal instrumentation of the spine via screw-rod systems have increased dramatically in recent decades, especially due to improved treatment options for (osteoporotic) fractures of the spine as well as spinal metastases. Simultaneously, caused by the demographic change an aging population is expected with a rising life expectancy. The aim of this study was to project the surgical volume of dorsal spinal instrumentation over the next 40 years to anticipate the medical and economic burden of this procedure on the future health care system in an industrialized country.

**Methods:** Comprehensive nationwide data provided by the Federal Statistical Office of Germany was used to quantify dorsal instrumentation rates as a function of age and gender. Projections were compared and performed with use of a Poisson regression models as well as exponential smoothing and autoregressive integrated moving average models on historical procedure rates from 2005 to 2019 in relation to official population projections from 2020 to 2060, and the most accurate model was chosen.

**Results:** The incidence rate of dorsal instrumentation of the spine is projected via exponential smoothing modeling to increase by around 211 % to 274.92 per 100,000 inhabitants [95 % CI 267.03 – 390.46], leading to a projected total number of 219,086 surgeries in 2060 [95 % CI 212,797 – 311,164] in 2060. This increase has been related to a growing number dorsal instrumentations performed in male and female patients over 75 years of age.

**Discussion:** Using this country specific projection model, a rapidly growing number of dorsal instrumentations of the spine has been projected, which accounts for a large and increasing burden on the German society and economy. These forecasts are alarming for other industrialized countries worldwide facing a similar demographic change. This study highlights the need for appropriate treatment concepts especially in elderly patients, including prevention of osteoporotic fractures, and post-operative rehabilitation concepts as well as an appropriate management of human and financial recourses.

#### P 092

##### A unicentric retrospective study of 139 sacroiliac joint fusion cases using triangular titanium implants

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##### Background:

Sacroiliac joint (SI) pain is an often-underestimated and underdiagnosed cause of low back pain, as it can mimic discogenic or radicular pain, and can also present as low back, hip, groin and/or buttock pain. Frequently there is a lack of specific findings on radiographs and symptoms mimic other back-related disorders. Failure of conservative therapy led to the development of SIJ arthrodesis procedures becoming increasingly used. We report on our experience with minimally invasive (MIS) SI joint arthrodesis using triangular, titanium plasma spray (TPS) coated implants in patients refractory to conservative care.

**Materials and Methods:** We report outcomes of 139 procedures with 12 to 36 months of postoperative follow-up using the clinical history and a questionnaire. All SI joint arthrodesis surgeries were done by a single group of neurosurgeons. Demographics, complications, and clinical outcomes using visual analog scale (VAS) for pain and Oswestry Disability Index (ODI) for back function were collected pre- and post-operatively. The presence of previous spine lumbar arthrodesis, the BMI, and smoking history were compared.

**Results:** Mean age was 55 years and 73% of patients were female. 100% of the patients had received diagnostic and therapeutic SI joint infiltrations (2 or more each joint) and/or thermal ablation or radiofrequency therapy before the surgery. 52% had undergone lumbar spinal fusion previously. There were no intraoperative complications and 8 revisions (5.7%) due to symptomatic implant loosening and S1 root syndrom. 13 (9.3%) patients needed a SI-fusion in the opposite side. All patient-reported outcomes, despite BMI, smoking history and previous arthrodesis showed both clinically and statistically significant improvement at 12 months ( $p < 0.001$ ). VAS improved by 5 points and ODI scores improved by 13.9 points average. Patient satisfaction with the outcome was high. 80% of the patients responding to the questionnaire would agree to have the same surgery again.

**Conclusions:** MIS SI joint fusion, regardless of previous lumbar spine fusion history, BMI and smoking using triangular porous TPS coated titanium implants is a safe and effective procedure for patients with SI joint disorders who have failed conservative care.

**Keywords:** minimally invasive surgery, sacroiliac joint fusion, SI fusion, previous spine surgery, complication.

**P 093**

**Non-cadaveric spine surgery training course – a survey among neurosurgical residents and proposal for future curriculum**

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**Objective:** Non-cadaveric spine surgery models for microsurgical skill training are still scarce and rarely part of neurosurgical curricula. The aim of our survey was to assess the usability of a non-cadaveric spine surgery course and its potential integration into the residency training program. Further, we explored the acceptance of the exoscope in the spine surgery course setting.

**Methods:** 16 neurosurgical residents in the 1st to 6th year of training used the *Realist RealSpine* model with the herniated disc L4/L5 scenario either with the microscope or the exoscope. A survey was then conducted with emphasis on usability of the model, exoscope experiences and acceptance of such a setting as part of a future curriculum.

**Results:** The spine model was rated 9.57 on a scale of 10, with 10 being "extremely useful" for surgical skills training. All participants indicated that they would like the course to become an integral part of their neurosurgical training. In their opinion, the most appropriate time for such a training would be the first or second year of residency. 81.3% participants actively used the exoscope in the spine course. Among them, the exoscope was considered equivalent to the microscope. Overall, 93.8% could imaging to continue/start their neurosurgical training with the exoscope.

**Conclusion:** The response to the non-cadaveric spine surgery training course was overwhelmingly good among our neurosurgical residents. The opportunity to explore a new technology like the exoscope was also very well received. Based on this initial experience, we will now work to incorporate the non-cadaveric spine model into the 1st and 2nd year of neurosurgical training and prospectively study the learning curve in the OR and surgical outcomes.

**P 094**

**Spine surgeons have the highest weighted relative citation ratio among all orthopaedic subspecialties**

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**Objective:** The Hirsch index (H-index) has been a popular bibliometric tool for the measurement of scientific impact. The

National Institutes of Health (NIH) has recently endorsed the relative citation ratio (RCR) as a novel instrument which allows publications to be both field- and time-normalized. Orthopaedic spine surgery is historically a highly productive field. In this study, we analyzed RCR and h-index scores for 2,812 academic orthopaedic surgeons from 131 residency programs. We further examined how distribution of demographic variables differed between spine and non-spine orthopaedists.

**Materials/Methods:** Academic orthopaedic programs in the United States were identified using the 2022 Fellowship and Residency Electronic Interactive Database (FREIDA). Available demographic and training data for orthopaedic surgeons was collected from institutional websites and Doximity. Orthopaedic surgeons were assigned to a subspecialty based on their completed fellowships. The "other" subspecialty category consisted of surgeons who completed arthroscopic surgery, limb lengthening, hip and joint preservation, metabolic bone disease, non-hand plastic & reconstruction, and neuro-orthopaedic fellowships. RCR was calculated using the NIH iCite tool, and h-index was calculated using Scopus. RCR equals citations of a publication, normalized to the citations received by NIH-funded publications in the same field and year. Mean RCR (m-RCR) is the average of RCR scores, and weighted RCR (w-RCR) is the sum of all RCR scores. Univariate chi-square analysis was used to determine differences in distribution of demographic variables. Multivariate analysis was used to calculate odds ratios. Statistical analyses were conducted using IBM SPSS Version 28.

**Results:** There were differences in distribution of gender, faculty rank, and number of fellowships between non-spine orthopaedic surgeons and orthopaedic spine surgeons (Table I). Spine surgeons had the second highest median h-index and were tied for the third highest median m-RCR. Spine surgeons had the highest median w-RCR. The Kruskal Wallis test demonstrated significant differences in median h-index, m-RCR, and w-RCR between subspecialties (Table II). After controlling for all other demographic variables, spine surgeons were 1.47 (95% CI: 1.13 – 1.90) times more likely to achieve 75th percentile m-RCR scores than non-spine orthopaedic surgeons.

**Conclusion:** Gender disparity and professorship were more pronounced in spine than non-spine orthopaedics. Among nine subspecialties, spine surgeons had the highest w-RCR and second highest H-indices. Spine surgeons had the fourth highest m-RCR. RCR can be used in conjunction with H-index to better assess research impact and productivity in academic spine surgery.

**Fig. 1**

Characteristic	Number of Non-Spine Orthopaedic Surgeons (%)	Number of Spine Surgeons (%)	P value
Gender			< 0.001
Men	2132 (86.1)	321 (95.8)	
Women	345 (13.9)	14 (4.2)	
Faculty rank			0.014
Assistant professor	1196 (48.3)	138 (41.2)	
Associate professor	635 (25.6)	86 (25.7)	
Full professor	646 (26.1)	111 (33.1)	
Years in Practice			0.312
0-10	972 (39.2)	120 (35.8)	
11-20	682 (27.5)	92 (27.5)	
21-30	474 (19.1)	78 (23.3)	
31+	349 (14.1)	45 (13.4)	
Number of Fellowships			< 0.001
0	166 (6.7)	-	
1	1973 (79.7)	269 (80.3)	
2	270 (10.9)	47 (14.0)	
3+	68 (2.7)	19 (5.7)	

Table 1: Demographics of Academic Non-Spine Orthopaedic Surgeons (N = 2477) versus Academic Spine Surgeons (N = 335)

Fig. 2

	Subspecialty	Number of Surgeons	Median	IQR	P value		
H-index	Spine	321	12	5-25	< 0.001		
	Adult reconstructive	351	11	5-19			
	Foot and ankle	200	9	4-17			
	Sports medicine	491	11	4-22			
	Trauma	374	8.5	4-16			
	Pediatrics	326	8	3-15			
	Hand and upper extremity	335	8	4-15			
	Musculoskeletal oncology	157	11	6-20			
	Shoulder	133	10	4.5-19.5			
	Other	63	13	6-22			
	m-RCR	Spine	318	1.81		1.23-2.39	< 0.001
		Adult reconstructive	347	1.93		1.36-2.52	
Foot and ankle		198	1.64	1.06-2.24			
Sports medicine		484	1.88	1.20-2.54			
Trauma		371	1.53	1.07-2.03			
Pediatrics		326	1.33	0.95-1.77			
Hand and upper extremity		331	1.41	0.97-1.79			
Musculoskeletal oncology		155	1.26	0.88-1.80			
Shoulder		131	1.81	1.44-2.25			
Other		63	1.84	1.30-2.50			
w-RCR		Spine	318	41.20	9.42-91.54	< 0.001	
		Adult reconstructive	347	35.00	10.80-101.61		
	Foot and ankle	198	21.86	5.50-72.45			
	Sports medicine	484	30.63	6.93-80.23			
	Trauma	371	24.63	7.20-65.67			
	Pediatrics	326	17.78	4.95-52.03			
	Hand and upper extremity	331	20.22	5.75-52.57			
	Musculoskeletal oncology	155	28.61	9.75-74.17			
	Shoulder	131	32.86	11.04-75.02			
	Other	63	38.06	16.74-96.94			

\*H-index was not available for 206 surgeons who were included in the study. M-RCR and w-RCR were not available for 233 surgeons who were included in the study.

Table II: H-index, m-RCR, and w-RCR of Academic Spine Surgeons

#### P 095

##### Effects of the SARS-CoV-2 pandemic on residency training in orthopedics and traumatology in Germany – a nationwide survey

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**Background:** The spread of the coronavirus disease has impacted health care systems worldwide. However, restrictions due to the SARS-CoV-2 pandemic are particularly drastic for physicians in residency training. Imposed restrictions interrupt the standard educational curricula, and consequently limited residents to meet mandatory requirements.

**Aim:** The aim of this study was to evaluate the effects of the SARS-CoV-2 pandemic on residency training in orthopaedics and trauma surgery in Germany.

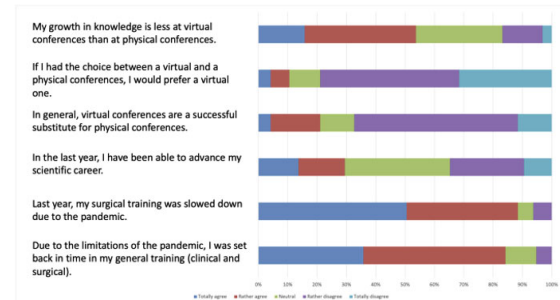
**Methodology:** An online-based, voluntary, and anonymous cross-sectional study was conducted to survey physicians in residency training. Through email lists of junior physician organizations the survey was sent to 789 physicians. Participation was possible between October and November 2021.

**Results:** 95 participants (f:41.1%) with a mean age of 31.3±2.8 years were analyzed. In the everyday clinical practice and care, 80% of participants thought, that they were set back in time of their general training due to the pandemic. There was an average reduction of 25.0% in time spent in the OR and 88.4% agreed that their surgical training was delayed due to the pandemic. 33.6% of respondents were able to attend external continuing education courses. Only 4.2% were able to invest more time in research.

55.8% of participants agreed that their residency training will be extended due to the pandemic.

**Conclusion:** The COVID pandemic has dramatically affected the residency training in orthopedics and trauma surgery in Germany. In almost all areas of training, residents had to accept restrictions due to the imposed restrictions, which potentially negatively affected their training.

Fig. 1



#### P 096

##### The effect of cage shape, position and material on segmental stabilization and bone loading in posterior, lateral and anterior lumbar interbody fusion techniques – a finite element perspective

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**Introduction:** Different techniques and options such as PLIF, TLIF, LLIF and ALIF are available to the surgeon for interbody fusion in the lumbar spine. To better understand the effect of cage shape, position and material on segmental stabilization and bone loading, and in order to better assess the biomechanical performance of these techniques, they were compared in a finite element (FE) model of the lumbar spine. **Materials and Methods:** A nonlinear FE model of a lumbar spine with reduced bone strength was developed and validated by comparing its range of motion with literature data. A specific model was then prepared for every technique and variant. Bilateral facetectomy with laminectomy for PLIF, right facetectomy for TLIF and removal of the anterior longitudinal ligaments for ALIF were performed in level L4-L5. Moreover, discectomy as well as placement of cages and posterior screw instrumentation were modeled in all spines at this level. The implanted cages were bilateral PLIFs, an oblique TLIF as well as banana TLIF cages with central and anterior positions, a LLIF and an ALIF (Figure 1). All PLIF and TLIF models had identical cage to endplate contact surface area and all cages were modeled using titanium as well as PEEK material properties. The spine was subjected to a follower load of 400 N and a flexion of 7.5 Nm, the expected maximum loading condition.

**Results:** ALIF, closely followed by LLIF and anterior banana TLIF achieve the highest stabilization, PLIF the lowest. ALIF, LLIF and anterior banana TLIF result in the lowest normalized mean cage sinking, oblique TLIF in the highest. And again ALIF, LLIF and anterior banana TLIF result in the lowest plastically deformed bone volume, PLIF in the highest. The results for titanium and PEEK cage material were similar (Figure 2).

**Discussion:** Our finite element model shows a higher segmental stabilization, a lower cage sinking and a lower volume of plastically deformed bone with ALIF, LLIF and anterior banana TLIF. From a biomechanical perspective, these techniques have the potential to lead to better disc height restoration, improve maintenance of correction over time and reduce the risk of cage subsidence and pedicle screw loosening. As a next step these findings should be further validated in corresponding clinical studies.

Fig. 1

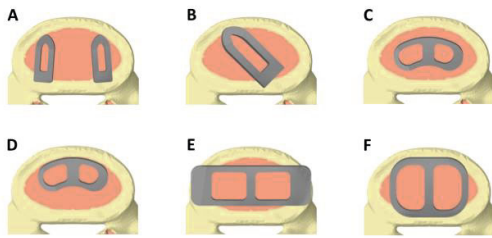


Figure 1: Top view of L5 showing cage position on endplate: PLIF, oblique TLIF (B), central (C) and anterior banana TLIF (D), LLIF (E) and ALIF (F)

Fig. 2

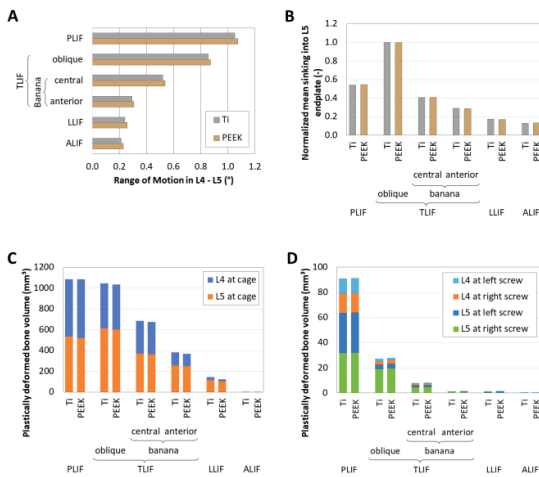


Figure 2: Remaining range of motion in stabilized segment L4 – L5 (A), Normalized mean sinking of cage into L5 endplate (B), Plastically deformed bone volume in the vicinity of cage (C) and screws (D)

P 097

Investigation of vertebral body cancellous bone and pullout force of pedicle screws as a function of BMD and Hounsfield-Units

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**Background:** The primary stability of dorsal instrumented pedicle screws depends on many factors. One of the most important factors is the bone quality measured by bone mineral density (BMD). The gold standard for this is dual-energy X-ray absorptiometry (DEXA). Alternatively, Hounsfield-Units (HU) from diagnostic CT examinations can be used. Objective of this study was therefore to investigate the dependence of bone strength as well as screw pullout force on HU and BMD.

**Methods:** Both DEXA and CT were obtained from 38 vertebral bodies (T6-L5) from a total of 5 body donors. BMD was determined for levels L1-L4, and HU for all tested vertebral bodies. Polyaxial pedicle screws were instrumented randomly in each vertebra on one side (left or right) in a classic trajectory, and the vertebral bodies were fixed with cast resin in a cylindrical sleeve. During axial pullout test (according to ASTM F35-17), the maximum pullout force  $F_{max}$  was determined. A cylindrical specimen (Ø6x12mm) was taken in superior/inferior direction on the non-instrumented side using a stationary drilling machine (Figure) and the parameters modulus (E), compressive strength ( $\sigma_{max}$ ) and plateau stress ( $\sigma_p$ ) were determined in uniaxial compressive test. Partial volumes of each vertebral body were

created using Materialise Mimics and the side-specific mean HU was determined. The relationships between bone density and the mechanical test data were presented based on regression analysis.

**Results:** All pairs of parameters yield significant results.  $F_{max}$  can be predicted very accurately by HU ( $R^2=0.83$ ) and BMD ( $R^2=0.91$ ). In contrast to BMD, HU can be determined for all investigated vertebrae, which is reflected in the number of cases. The mechanical parameters of the vertebral cancellous bone can be predicted similarly well by HU and BMD. Here,  $\sigma_{max}$  achieves the best model quality.

**Conclusion:** The prediction of bone strength as well as primary stability of implants by standard imaging techniques has a great potential for application in clinical practice. The compressive strength of lumbar vertebral body cancellous bone can be predicted well by BMD and HU. Thus, outside the measurement range of DEXA, diagnostic CT can provide quantitative information on bone architecture and quality. Detailed knowledge of bone architecture and quality in the effective range of implants can be used to derive an individually adapted treatment strategy and thus reduce the risk of complications.

Tab.: Results of curve fit using power functions ( $y=a*x^b$ ) with the side-specific HU or BMD as dependent variables.

Fig.: Embedded vertebral body (center). Pedicle screw in axial pullout (left) and cancellous bone specimen in compressive test (left).

Fig. 1

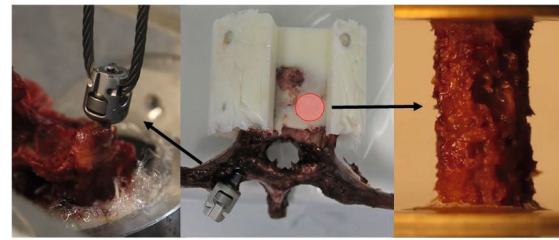


Fig. 2

	N	R <sup>2</sup>	P-Wert	a	b
$F_{max}$ vs. BMD	10	0,912	<0,001	694,273	3,196
$F_{max}$ vs. HU	24	0,829	<0,001	2,765	1,042
E vs. BMD	14	0,447	0,009	73,246	2,119
$\sigma_{max}$ vs. BMD	14	0,695	<0,001	1,167	2,950
$\sigma_p$ vs. BMD	14	0,603	0,001	0,914	3,458
E vs. HU	37	0,423	<0,001	0,097	1,231
$\sigma_{max}$ vs. HU	37	0,632	<0,001	0,001	1,332
$\sigma_p$ vs. HU	37	0,603	<0,001	0,123	0,009

P 098

Concepts for increasing the primary stability of pedicle screws using active and superelastic shape memory elements

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**Introduction:** In the context of medical conditions that affect bone quality, the anchoring strength of pedicle screws has an impact on the success of spinal restorations. Functionalised implants with integrated elements made of shape memory alloys (SMA) are an innovative approach to increase the anchoring strength. SMAs can change their shape when thermally activated and can thereby perform work. In addition, their superelastic properties make them suitable as passive mechanical dampers.

The aim of this work was to develop concepts to increase the anchoring strength of pedicle screws by integrating shape memory elements and to test them biomechanically.

**Material/Method:** Conventional screw implants were mechanically machined and modified in order to integrate functional elements based on SMA (see Fig. 1).

Concept 1 implements active anchoring in the bone. After implantation, body heat activates a shape memory element that leads to a local dilatation of the screw diameter by means of an expansion mechanism. The expansion elements are localized below the screw head to provide additional clamping in the pedicle region.

Concept 2 utilises the passive superelasticity of SMA. The non threaded section of the screw below the head is replaced by a cylindrical shape memory element. Part of the deformation energy introduced at the screw head by attached rod systems dissipates through the superelastic material behaviour, so that loads are damped.

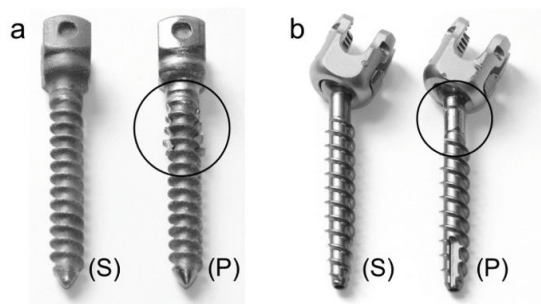
Fig. 1: Prototype (P) and standard screw (S), a – concept 1 (active), b – concept 2 (passive)

The biomechanical testing was carried out in a test setup for cyclic screw loosening according to ASTM F1717 with subsequent axial pull-out.

**Results:** In comparison to the standard screw of identical design, both concepts tended to show lower relative movements between the screw head and the human bone. In addition, concept 2 resulted in a higher residual pull-out force after loading. Under the applied cyclic loading, implant failure due to material fatigue occurred for both the prototypes and the conventional screws.

**Discussion:** Functionalisation of pedicle screws with shape memory elements is technically feasible and provides a promising approach to increase primary stability. Both active anchoring (concept 1) and damping of the applied cyclic load (concept 2) showed potential for increased anchoring strength. The increased pullout force of Concept 2 suggests sparing of the bone under cyclic loading. The observed material failure indicates deficiencies in fatigue strength due to generative manufacturing and requires further optimisation.

Fig. 1



P 099

### The three-dimensional bone microstructure of the axis and clinical implications

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**Introduction:** The fracture of the dens axis (DAX) of type II according to Anderson and D'Alonzo (DFTII) is common, especially in geriatric patients, and pseudarthrosis and material loosening may occur after osteosynthesis using ventral Böhler screws (BS). In this context, the bone microstructure of the axis (C2) seems to be a relevant factor for stability. Therefore, the

present study aims to analyze the bone microstructure of the C2 using high-resolution quantitative computed tomography (HR-pQCT) to find correlations in a clinical collective analyzed by classical computed tomography (CT), and to derive clinical implications.

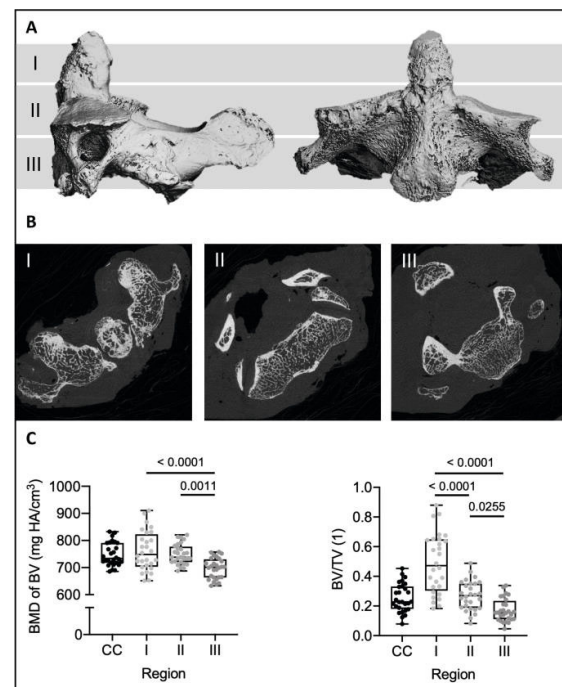
**Material/Methods:** First, a retrospective analysis of Hounsfield units (HU) was performed in a clinical collective (n = 20; 50% women) with a mean age of 81.6 ± 9.2 years, using CTs of C2. HU were measured separately for zones I, II, and III according to Anderson and D'Alonzo (Fig. 1A). Subsequently, cadaveric human C2 (n = 28; 50% women; 80.8 ± 13.9 years) were analyzed by HR-pQCT. Analogous to the zoning mentioned above, bone volume/tissue volume (BV/TV) and bone mineralization (BMD of BV, mg HA/cm<sup>3</sup>) were determined, among others (Fig 1B). This was followed by a comparative statistical analysis of the measured values of the respective zones using ANOVA and Tukey post-hoc test.

**Results:** CT measurements showed significantly lower HU in zones II (248.0 ± 161.8) and III (246.0 ± 92.1) compared to zone I (541.5 ± 257.0) (zone I vs. II p < 0.001; zone I vs. III p < 0.001; zone II vs. III p = 0.308). HR-pQCT showed a mean BV/TV in zone I of 0.49 ± 0.20, in zone II of 0.27 ± 0.09, and in zone III of 0.17 ± 0.07 (zone I vs. II p < 0.0001; zone II vs. III p = 0.025; zone I vs. III p < 0.0001) (Fig. 1C). There was also a significant reduction in the BMD of BV from zone I apparent (760.90 ± 72.91) to zone II (748.32 ± 37.49) to zone III (696.57 ± 38.23) (zone I vs. II p = 0.0011; zone II vs. III p = 0.6412; zone I vs. III p < 0.0001) (Fig. 1C).

**Discussion:** The C2 is characterized by decreasing trabecular microstructure from the apex to the bottom, indicating poorer bone stability in zones II and III. These findings may proportionately explain the increased fracture susceptibility of zones II and III compared with zone I. In addition, the lower bone quality in zones II and III appears to be a risk factor for implant loosening after ventral BS osteosynthesis.

**Fig.1:** A: Zonal classification of the axis (I-III) according to Anderson and D'Alonzo. B: Axial sections from high-resolution peripheral quantitative computed tomography (HR-pQCT) in the respective zones I-III. C: Results of bone volume/tissue volume (BV/TV) and bone volume mineralization (BMD of BV) of C2 analyzed by HR-pQCT.

Fig. 1



**P 100****Is human bone matrix a sufficient augmentation method revising loosened pedicle screws in osteoporotic bone? A biomechanical evaluation of primary stability**\*P. Egenolf<sup>1</sup>, A. Harland<sup>1</sup>, M. Weber<sup>1</sup>, A. Prescher<sup>2</sup>, G. Bratke<sup>1,3</sup>, P. Eysel<sup>1</sup>, M. J. Scheyerer<sup>1</sup>, M. Lenz<sup>1</sup><sup>1</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>2</sup>Universitätsklinik RWTH Aachen, Institut für molekulare und zelluläre Anatomie, Aachen, Deutschland<sup>3</sup>Universitätsklinikum Köln, Institut für diagnostische und interventionelle Radiologie, Köln, Deutschland

**Background:** Despite good anchoring and safe trajectory of pedicle screws, screw loosening can occur, especially in people with osteoporosis. The aim of this biomechanical analysis was to evaluate the primary stability of revision screw placement in individuals with osteoporosis. The compared revision techniques were on one hand a screw with an enlarged diameter by 2 mm and on the other hand the use of human bone matrix (HBM) as an augmentation for a screw with the same diameter. The idea of HBM augmentation is to improve the bone stock and thus achieve better screw coverage.

**Methods:** Eleven cadaveric lumbar vertebrae with a mean age of 80.25 years ( $\pm 12.79$  years) and a mean bone mineral density of 90.32 Hounsfield units (HU) were used. Pedicle screws 6.5 mm in diameter and 45 mm in length were placed in both pedicles and then loosened using a cyclic cranio-caudal fatigue protocol. Screw loosening was defined as displacement of the screw head by 5 mm. After removal of the loosened screws, the screws were revised by inserting a 2mm larger diameter screw (8.5x45mm) in one pedicle and a screw of the same diameter (6.5x45mm) with HBM augmentation in the other pedicle. The previous relaxation protocol was then re-applied, comparing maximum loading and cycles to failure between both revision techniques. The insertional torque (IT) was continuously measured during the insertion of both revision screws.

**Results:** The number of cycles ( $p = 0.041$ ) and the maximum load to failure ( $p = 0.014$ ) were significantly higher for larger diameter screws than for augmentation with HBM. In addition, both the maximum ( $p=0.004$ ) and mean IT ( $p=0.033$ ) of the enlarged screw were significantly higher than the IT of the revised screw with HBM.

**Interpretation:** HBM augmentation does not achieve the same ad hoc fixation strength as the 2 mm screw diameter increase and is therefore biomechanically inferior. A thicker screw should therefore be prioritized for immediate stability.

**P 101****Utilizing a torque-based screwdriver to map bone quality and predict implant failure – a biomechanical analysis**\*J. P. Eysel<sup>1</sup>, P. Egenolf<sup>1</sup>, M. Lenz<sup>1</sup>, M. J. Scheyerer<sup>2</sup><sup>1</sup>Universitätsklinikum Köln, Klinik für Orthopädie und Unfallchirurgie, Köln, Deutschland<sup>2</sup>Universitätsklinikum Düsseldorf, Klinik für Orthopädie und Unfallchirurgie, Düsseldorf, Deutschland

**Introduction:** The pedicle-based stabilization of the spine is one of the standard procedures in spine surgery today. In order to assess the bone quality, the surgeon has only a few intraoperative possibilities to draw conclusions about the quality of the bone in order to consequently modify the surgical measures – for example in the sense of an augmentation of the screws. Therefore, the aim of the present work was to examine the usefulness of a torque-based screwdriver for the evaluation of bone quality as well as for the prediction of implant failure.

**Material:** 13 lumbar vertebrae from exclusively male donors with a mean bone density of 101.2 Hounsfield units (HU) (SD 31.6) were used. After preparation and embedding, pedicle screws were inserted into both pedicles using an electric torque screwdriver (cordless pistol EC screwdriver with torque sensor HAST Technik, Efringen-Kirchen, Germany) and the torque was continuously documented. After fixing the base plate of the vertebral body in the plastic block, the measurement was carried out in the test machine

(Zwick/Roell Z010, Zwick Roell, Ulm, Germany). All samples underwent cyclic biomechanical testing with a lower interval of 25N to -25N in ascending cycles. Implant failure was defined as a movement of the screw heads  $\geq 5$  mm and/or a breach of the force cut-off threshold of 40% Fmax.

**Results:** There was a significant correlation between the maximum insertion moment (MIT) during the first half of insertion (H1) and the HU ( $p = 0.045$ ). The average insertion torque (AIT) in the second half as well as over the entire length also correlated significantly with the HU ( $p = 0.023$ ). The failure analysis showed a highly significant positive correlation of the AIT isolated for both H1 and H2 with the bolt strength. The higher the respective AIT, the higher the load (load to failure;  $p(H1)=0.000$ ;  $p(H2)=0.000$ ) and number of cycles (cycles to failure;  $p(H1)=0.002$ ;  $p(H2)=0.009$ ) until the screw loosens. With regard to the MIT, there is also a highly significant positive correlation for H1 with the screw strength ( $p=0.001$ ). However, the MIT of H2 does not significantly correlate with the number of cycles to failure.

**Discussion:** There is a significant correlation between the insertion torques and the determined HU. The AITs of H1 and H2 are particularly suitable as markers for the screw strength. The average and maximum torques over the entire course of the screw, on the other hand, are of little use.

**P 102****Nucleus pulposus digestion using chondroitinase or papain? Evaluation of their biomechanical effects and a new organ culture approach for in vitro testing of biomaterials**\*J. U. Jansen<sup>1</sup>, G. Quelhas Teixeira<sup>1</sup>, A. Vernengo<sup>2</sup>, S. Grad<sup>2</sup>, K. Benz<sup>3</sup>, C. Neidlinger-Wilke<sup>1</sup>, H. J. Wilke<sup>1</sup><sup>1</sup>Universitätsklinikum Ulm, Institut für Unfallchirurgische Forschung und Biomechanik, Ulm, Deutschland<sup>2</sup>AO Forschungsinstitut, Davos, Schweiz<sup>3</sup>TETEC Tissue Engineering Technologies AG, Reutlingen, Deutschland

**Introduction:** In the 1980s and 1990s, chemonucleolysis using enzymes such as chondroitinase ABC (ChABC) or chymopapain was one of the common therapeutic options for soft herniations of the intervertebral disc (IVD) [1]. Nowadays, these enzymes are used for artificial degeneration of animal IVDs and could also be used for in vitro experiments (e.g. with biomaterials (Bmat)). However, the biomechanical effects and structural changes of enzymatic digestion in the IVD have been investigated rarely. The aim of this study was to artificially degenerate bovine tail discs using enzyme digestion and to compare them after Bmat injection with respect to distribution in the IVD and biomechanical behavior.

**Material/Method:** In 3 of 4 groups ( $n=6$ ), bovine tail discs were injected with 1U ChABC, 13U papain or PBS, the IVDs were incubated for 7 days (6% O<sub>2</sub>, 37°C) and then complex loaded to compensate the cell culture medium swelling. The 4th group was freshly tested as a control and not incubated. After injection of a radiopaque hydrogel into all IVDs, its distribution was visualized by  $\mu$ CT. Range of motion (ROM) and disc height were determined before and after enzyme treatment, after loading, and after injection for all groups. Statistics: Mann-Whitney-U, Friedman, Benjamini-step-up ( $p \leq 0.05$ ).

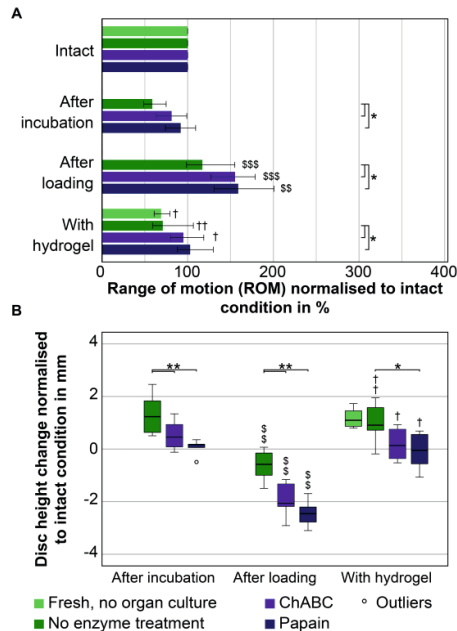
**Results:** Papain digested IVDs showed a cavity in the nucleus after incubation whereas IVDs from the other groups remained at least macroscopically intact. After incubation and loading, the disc height of enzyme-digested IVDs significantly decreased ( $p \leq 0.009$ ) and their ROM increased ( $p \leq 0.026$ ) (Fig1). Significantly more Bmat could be injected into enzyme-digested IVDs than into non-enzyme treated IVDs (Fig2 A/B,  $p=0.002$ ). The injected Bmat restored the intact disc height ( $p \leq 0.015$ ) and ROM ( $p \leq 0.037$ ) for ChABC and papain IVDs (Fig 1).  $\mu$ CT and subsequent macroscopy revealed fragmented Bmat regions for ChABC and a more homogeneous Bmat distribution for papain (Fig2 C).

**Discussion:** Both enzymes lead to macroscopically different results but similar biomechanical properties regarding ROM increase and disc height decrease. The additional cavities in the papain group mimic structural changes seen in human IVDs after prolapse or nucleotomy [2]. ChABC-induced matrix degradation more closely simulates age-related degeneration patterns without cavities. Since

equal amounts of Bmat can be injected into ChABC and papain digested IVDs, it can be hypothesized that the enzymes equally reduce intradiscal pressure. These results have improved our understanding of the biomechanical and morphological effects of ChABC and papain digestion, as well as facilitated the selection of appropriate enzymes for various in vitro tests involving Bmat injection.

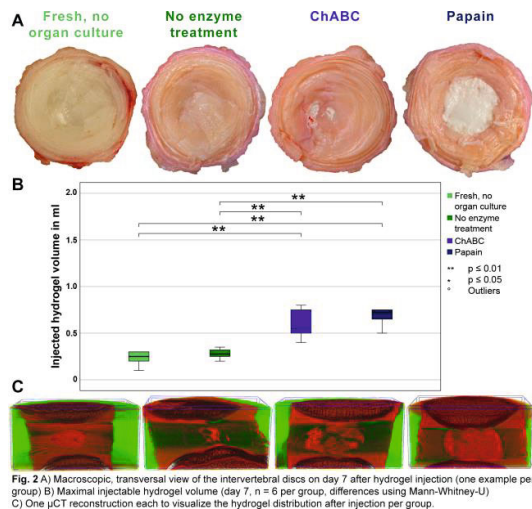
**Acknowledgments:** iPSpine (825925). [1] Wardlaw 2016 [2] Wilke et al. 2013

**Fig. 1**



**Fig. 1** Range of motion for flexion-extension (A) and disc height change normalized to the intact condition (B) shown by group and time point (condition). Statistics with  $p < 0.05$ . \* significant differences between groups at given conditions (Mann-Whitney-U). \$ significant differences for given group between conditions "After loading" vs "After incubation" or † between "After incubation" vs "With hydrogel", respectively. (Friedman / Benjamini step-up)

**Fig. 2**



**Fig. 2** A) Macroscopic, transversal view of the intervertebral discs on day 7 after hydrogel injection (one example per group) B) Maximal injectable hydrogel volume (day 7,  $n = 6$  per group, differences using Mann-Whitney-U) C) One µCT reconstruction each to visualize the hydrogel distribution after injection per group.

**P 103**  
**Do reduction and tightening of the screw-rod construct affect pedicle screw anchorage? A biomechanical study**  
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<sup>2</sup> Universitätsmedizin Mainz, Mainz, Deutschland

**Introduction:** Pedicle screw loosening is one of the most common complications following instrumented posterior fusion. An

incidence of up to 15% has been reported in good bone quality; osteoporotic bone increases the risk fourfold. Evidence suggests that most screws later identified as loosened were initially pulled out during reduction and tightening of the screw-rod connection. These interventions can lead to overloading of the implants and surrounding tissues, which is associated with an increased risk of revision surgery. The aim of this study is to investigate the effects of reduction and tightening and the influence of additional distraction forces on pedicle screw anchorage during construct assembly and final locking.

**Material/Methods:** Two human cadaver specimens (13 segments, T5-S1) were stabilized in direct side-by-side comparison using pedicle screw rod systems following different philosophies: force-controlled fixation (FCF: Neo Pedicle Screw System) and standard fixation (SF: CD Horizon Solera). Insertion torques (IT) and, after assembly, final tightening and a short period of settling, extraction torques (ET) were measured digitally. The impact of reduction and final tightening was evaluated by comparing the losses between IT and ET. In addition, the effect of distraction forces (100N) applied across pedicle screw heads was investigated in polyurethane foam blocks of certain densities. Statistical significance at  $p < 0.05$ , Mann-Whitney U test for comparisons and correlation analyses according to Spearman.

**Results:** With FCF, the median torque loss was significantly lower (0.393Nm) than with SF (0.539Nm) ( $p < 0.001$ ). Despite higher ITs with SF (0.966 vs. 0.747Nm), ETs were similar (0.344 vs. 0.301Nm) (Fig.1). IT and ET correlated statistically significant (FCF:  $r = 0.792$  and SF:  $r = 0.783$ ;  $p < 0.001$ ). Torque losses were higher in both groups when additional distraction forces were applied directly across pedicle screw heads ( $p \leq 0.041$ ).

**Discussion:** Reduction and tightening of the rod-screw interface have a significant impact on pedicle screw anchorage. The loss between IT and ET quantifies the loss of biomechanical behavior and consequently the load transferred to the instrumentation and the surrounding tissue. It is lower if the instrument assembly is performed force-controlled. This can be attributed to the fact that in force-controlled techniques, lower forces are applied intraoperatively. As a result, the patient's individual anatomical and biomechanical balance can be better addressed. This has the potential to reduce pedicle screw loosening, construct failure, and reoperation rates, and improve clinical outcomes.

**Fig. 1**

Measure	Group	N (valid)	Median-Torque [Nm]	25%-75% Torque Interval [Nm]	P
IT	FCF	28	0.747	0.503 - 0.931	0.004
	SF	28	0.966	0.724 - 1.327	
ET	FCF	28	0.301	0.156 - 0.447	0.272
	SF	28	0.344	0.191 - 0.675	
Delta	FCF	28	0.393	0.233 - 0.507	<0.001
	SF	28	0.539	0.437 - 0.681	

**Figure 1:** Cadaver measurements by fixation philosophy. IT and ET after reduction and tightening of the screw-rod assembly for FCF and SF. IT, insertion torque; ET, extraction torque; Delta, IT - ET; FCF, force-controlled fixation; SF, standard fixation; P, between group p-value (FCF vs. SF, Mann-Whitney U-Test)

**Fig. 2**

Messung	Gruppe	N (gültig)	Drehmoment Median [Nm]	Drehmoment 25%-75% Konfidenzintervall [Nm]	P
IT	FCF	28	0.747	0.503 - 0.931	0.004
	SF	28	0.966	0.724 - 1.327	
ET	FCF	28	0.301	0.156 - 0.447	0.272
	SF	28	0.344	0.191 - 0.675	
Delta	FCF	28	0.393	0.233 - 0.507	<0.001
	SF	28	0.539	0.437 - 0.681	

**Abbildung 1:** In-vitro-Messung je Fixationsphilosophie. IT und ET nach Reposition und dem Festziehen der SSV für FCF und SF. IT, Eindrehmoment; ET, Ausdrehmoment; Delta, IT - ET; FCF, Kraftkontrollierte (Force-controlled) Fixation; SF, Standard-Fixation; P, p-Wert (Mann-Whitney-U-Test)



## P 104

**Anterior cervical column reconstruction with the new expandable PEEK vertebral body replacement device ECD – safety and effectiveness**M. Stefanides<sup>1</sup>, \*K. A. C. Oswald<sup>1</sup>, A. Luyet<sup>1,2</sup>, C. E. Albers<sup>1</sup>, M. C. Deml<sup>3</sup><sup>1</sup>Inselspital, Bern University Hospital, Orthopädische Chirurgie und Traumatologie, Bern, Schweiz<sup>2</sup>EHC Hospital Morges, Spine Surgery, Morges, Schweiz<sup>3</sup>Inselspital, Bern University Hospital, Orthopädische Chirurgie und Traumatologie, Bern, Schweiz

**Introduction:** Anterior cervical corpectomy and fusion (ACCF) has been established as a favorable and safe surgical procedure to stabilize the anterior cervical vertebral column. Recently, the PEEK vertebral body replacement device (VBR) ECD cage was introduced, providing personalized individual adaptation through expandability, better stress distribution, and radiolucency compared to previous systems. This study aimed to assess the safety and efficacy of the ECD by analyzing (1) radiographic outcome, (2) clinical outcome, and (3) complication rates.

**Materials/Methods:** In this retrospective cohort study, 28 patients (61±13 years; 64% female), who underwent ACCF with the novel expandable PEEK-VBR ECD cage (Fig1) for metastatic, traumatic or degenerative disease between 2011 and 2020, were included. Median follow-up was 1.0 [0.6; 1.8] years with a minimum follow-up of 6 months. Correction of the bisegmental kyphotic angle (BKA) was defined as the primary outcome. Bony fusion, loss of device height, and implant subsidence were evaluated additionally. Clinical outcome was evaluated using Odom's criteria, numerical pain rating scale (NRS), ASIA Impairment Scale (AISA), and Karnofsky Performance Status Scale (KPSS). Parameters were analyzed preoperatively, directly postoperatively, six weeks-, six months postoperatively as well as at final follow-up.

**Results:** Directly postoperatively, BKA was improved by mean 13.5±9.7 degrees compared to preoperatively (p<0.0001). At final follow-up, mean correction remained at 12.3±9.6 degrees compared to preoperatively (p=0.0002). At the last follow-up, no loss of device height (p=0.96) nor implant subsidence occurred compared to directly postoperatively (p=0.99). Bony fusion was observed in all patients with Grade I in 53% and Grade II in 47% according to Eck's Criteria. Clinical outcome (Fig2) – Odom's criteria, pain and AISA- showed favorable improvement at final follow-up compared to the preoperative state (p=0.07). In patients suffering from tumorous disease, KPSS improved significantly to mean 62±10 directly postoperatively compared to preoperatively (p=0.0009) and showed no significant decrease at final follow-up compared to directly postoperatively (p=0.3). Four patients underwent secondary posterior stabilization. In one case, the ECD had to be explanted due to a major surgical site infection after an incidental esophageal lesion.

**Discussion:** This is the first study analyzing the radiologic and clinical outcome of the ECD PEEK cage in the cervical spine. The study revealed that the ECD restored and maintained the anterior vertebral column in the cervical spine in patients with metastatic, traumatic, and degenerative diseases. The rate and degree of complications did not exceed these in other surgical treatment modalities for these pathologies. Thus, the ECD PEEK cage is a safe and efficient therapy option for anterior vertebral column reconstruction.

Fig. 1

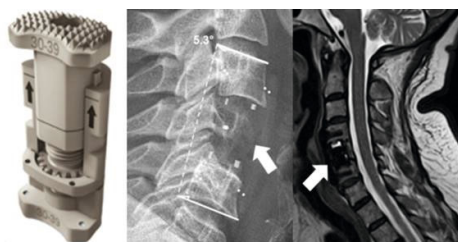
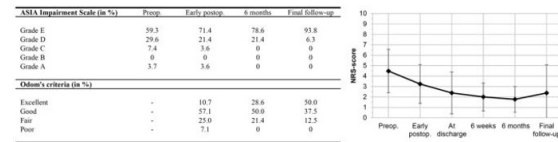


Fig. 2



## P 105

**In vitro 3D degenerative nucleus pulposus micro-tissue model to assess the preconditioning of nasal chondrospheres for intervertebral disc regeneration**J. Kasamkattil<sup>1,2</sup>, A. Gryanunova<sup>1,2</sup>, R. Schmid<sup>1,2</sup>, M. Gay<sup>3</sup>, B. Dasen<sup>4,2</sup>, I. Martin<sup>4,2</sup>, S. Schären<sup>1,4</sup>, A. Barbero<sup>4,2</sup>, O. Krupkova<sup>1,4,2</sup>, \*A. Mehrkens<sup>1,4,2</sup><sup>1</sup>Universitätsspital Basel, Klinik für Spinale Chirurgie, Basel, Schweiz<sup>2</sup>Departement Biomedizin Universität Basel, Tissue Engineering, Basel, Schweiz<sup>3</sup>Universität Basel, Anatomie, Basel, Schweiz<sup>4</sup>Basel Center of Regenerative Surgery, Basel, Schweiz

**Introduction:** Cell-based intervertebral disc (IVD) therapies are not successful because the degeneration of the IVD makes the already harsh microenvironment more hostile for cell survival. No satisfying *in vitro* system simulating the degenerative disc disease (DDD) has been engineered yet to study IVD cell treatment strategies. Therefore, the aim of this study is (i) to develop a 3D degenerative nucleus pulposus micro-tissue (NP $\mu$ T) model and (ii) to investigate the reaction of spheroids formed with nasal chondrocytes (NCS) within the model. FDA approved drugs with the potential to increase NCS performance within the DDD microenvironment were also tested.

**Material/Methods:** NP $\mu$ T was generated by pooling NP spheroids (NPS; 25'000 cells/spheroid) with or without NCS (12'500 cells/spheroid). NP $\mu$ T (+NCS) was cultured for 2 weeks in DDD-mimicking (inflammation, hypoxia, acidity, low glucose) condition. Preconditioning of the NC cells were performed first in 2D and then in 3D cultures. NCs were preconditioned (3 hours) in 2D culture with Amiloride, Metformin, Celecoxib, IL-1Ra, and GDF-5 and cultured for 24h in DDD-mimicking condition. For 3D culture, NCS were preconditioned (3 days) during its formation time with GDF-5, IL-1Ra, or combined and cultured for 7 days in DDD mimicking condition. Histological and biochemical analysis were performed to investigate ECM accumulation in the  $\mu$ T. ELISA (IL-8) was performed to assess the catabolic shift taking place within the  $\mu$ T. After NC and NCS preconditioning the relative gene expression of anabolic and catabolic markers was analysed (n=3-5).

**Results:** NP $\mu$ T formed in degenerated conditions accumulated significantly less proteoglycans/collagens and experienced catabolic shift compared to healthy control. NCS partially accumulated proteoglycans and collagens within the harsh DDD micromilieu. IL-1Ra- preconditioning downregulated the expression of catabolic and inflammatory markers (MMP-3 and IL-8) in NCS cultured within DDD-mimicking condition. GDF-5 significantly increased ACAN expression in 2D culture of NCs but did not upregulate the expression of anabolic genes in 3D cultured NCS. Amiloride, Metformin, and Celecoxib did not reduce inflammation.

**Discussion:** The 3D degenerative NP $\mu$ T model allows the NP cells to re-differentiate in spheroidal organization, to accumulate cell-produced matrix and to create an *in vitro* DDD microenvironment. NCS are partially producing ECM components within the degenerative NP $\mu$ T model. Our results suggest that NCS preconditioning is essential for increasing ECM accumulation within DDD, with IL-1Ra as promising candidate.

<b>A</b>		Berlemann, U.	V 28	Coric, D.	SP 03
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