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ORIGINAL ARTICLE

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The use of a retractor system (SynFrame) for open, minimal invasive reconstruction of the anterior column of the thoracic and lumbar spine

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Abstract In 65 consecutive cases of trauma (*n*=55), pseudo-arthrosis (*n*=4) and metastasis (*n*=6), anterior reconstruction of the thoracic and lumbar spine was performed using a new minimal invasive but open access procedure. No operation had to be changed into an open procedure. The thoracolumbar junction was approached by a left-sided mini-thoracotomy (*n*=50), the thoracic spine by a right-sided mini-thoracotomy (*n*=8) and the lumbar spine by a left sided mini-retroperitoneal approach (*n*=7), using a new table-mounted retractor system called SynFrame (Stratec Medical, Switzerland). The anterior column was reconstructed using a variety of materials: autologous tricortical crest (*n*=11), autologous spongiosa (*n*=12), allografts (*n*=4) and cages (*n*=38). The mean overall operating time was 170 min (range 90–295 min); the time of surgery varied, depending on the spine pathology and the magnitude of the intervention in the anterior part of the spine. Mean overall blood loss was 912 ml, and only 7 out of the 65 patients needed blood transfusions. There were neither intra- nor postoperative complications related to the minimal access in particular, nor visceral/vascular complications. No intercostal neuralgia, no post-thoracotomy pain syndromes, no superficial or deep wound infections and no deep venous thromboses occurred. Four cases of pseudo-obstruction were treated conservatively. In this study, we describe the new minimal access technology to the anterior part of the thoracal and lumbar spine on the basis of 65 cases completed within 1 year. This open, but minimal invasive, access technology offers, in our view, additional advantages to the "pure" endoscopic procedures of spinal surgery.

Keywords Minimal invasive spine surgery · Reconstruction · Anterior column · Retractor

Introduction

Minimal invasive approaches to the thoracic or lumbar spine were introduced in the early 1990s [18, 19], inspired by the success of endoscopic thoracic and abdominal surgery [17]. The main goal of these efforts has been the reduction of surgical trauma, since anterior open approaches to the thoracic or lumbar spine were associated with a significant complication rate [5, 7]. Major patients' complaints were intercostal neuralgia and post-thoracotomy pain syndromes [5, 9]. Already the first reports using minimal invasive technology for spine interventions have demonstrated a reduction of the access morbidity, reduced intraoperative blood loss, fewer days in intensive care and an overall reduction in the hospital stay [13, 18, 19, 20].

A variety of minimal surgery access strategies to the thoracic and lumbar spine have been developed in recent years, named either minimal invasive spinal surgery (MISS), video-assisted thoracoscopic surgery (VATS), laparoscopy-assisted spinal surgery or retroperitoneal endoscopic surgery [3, 13, 15, 19, 21]. The obvious advantages

of the minimal invasive strategies to the spine are diminished by the disadvantages due to increased anesthesiological monitoring, long learning curve for the surgeons, longer operation times and considerable financial investments for an endoscopic set-up and disposable instruments.

Interestingly, the initial euphoria over lumbar laparoscopic spinal fusions [4, 12, 14, 16, 18, 20] is giving way to a preference for a lesser invasive, but open access to the lumbar spine, for several reasons [6, 13]. A minimal invasive, but open procedure in the anterior part of the spine combines the above-mentioned advantages of the "pure" endoscopic approaches with the ones of an open procedure, i.e. direct view of the anterior part of the spine, safer mobilisation of nerves and vascular structures, faster decompression of the spinal canal and easier reconstruction of the anterior column.

The authors describe a new method in which the anterior column of the thoracic and lumbar spine was reconstructed through an open, but minimal invasive, approach with the use of the new retractor system, SynFrame [1]. The major advantages of this method are the direct three-dimensional view of the spine without the mandatory use of a thoracoscope and being able to dispense with double-lumen intubation, as well as a relatively short learning curve for the surgeons. During 1 year, 65 consecutive cases of anterior reconstruction of the thoracic and lumbar spine either after trauma or for metastasis removal were been performed using this minimal invasive but open access technology.

Materials and methods

Patients

Sixty-five consecutive patients (28 women, 37 men) were operated from July 1999 to July 2000 for traumatic injuries (n=55), metastasis (n=6) or pseudo-arthrosis (n=4) on the thoracic/lumbar spine. The mean age of the patients was 42 years (range 14–76 years). Indications for surgical treatment of the traumatic cases were their evaluation as unstable spine injuries according to the Magerl classification [11], neurological deficit, sagittal angulation of more than 25°, axial compression of more than 50% of vertebral height and multiple contiguous fractures. Twenty-nine patients required both an anterior and a posterior spinal intervention, using for posterior instrumentation the Universal Spine System (USS, Stratec Medical, Switzerland, also available from Mathys Medical Ltd, Switzerland), followed by an anterior column replacement with a variety of materials (Table 1). Six patients with metastasis to the spine of a variety of origins received replacement of the destroyed anterior column with a cage filled with acrylic cement. In four patients, a pseudo-arthrosis had occurred after a previous intervention. If necessary, an additional ventral stabilisation system was used (Ventrofix, Stratec Medical, Switzerland, also available from Mathys Medical Ltd, Switzerland).

Table 1 Material used for reconstruction of the anterior column

Anterior graft used	No of patients
Autologous tricortical iliac crest	11
Autologous spongiosa[a]	12
Allografts total	4
Femur	2
Iliac crest	2
Expandable cages (Synex)[a]	38
Acrylic cement	9

[a] Some materials were used in a combined manner

The SynFrame concept

The retractor system SynFrame (Stratec Medical, Switzerland, also available from Mathys Ltd, Switzerland) is a stable and adjustable ring system (Fig. 1A). It is fixed sterile by two adjustable arms onto the operating table, allowing a 360° surgical access from any point inside the ring [1]. One of the major advantages of this system compared to other minimal invasive procedures to the spine [3, 13, 15] is the permanent stability of the operation field, enabling the surgeon to perform a small access to the spine without further manipulation. The blades are clicked onto the ring (Fig. 1A, Fig. 2), and can be located at any point on the ring, depending on the requirements of the surgeon. In all of our cases, adjustable retractor blades were used, although the SynFrame system also offers the use of modified Hohmann levers [1]. The blades can be adjusted individually in all three planes due to their connections to the ring by a clamp. Different blade lengths, from 60 to 160 mm, are available for tissue retraction. A specially designed fiberoptic clamp (Fig. 1A, Fig. 3) allows the use of endoscopes of different angulations and sizes. The light source perfectly illuminates the depth of the operating field, and the endoscopic view allows visualisation of the procedures on a video screen. This enables nurses and assistants to follow the surgery, facilitating teaching, since the surgeon is the only one with a direct three-dimensional view of the operating field. This set-up was used in all surgeries to the thoracic spine and thoracolumbar junction, while only a fiberoptic light source was used in the mini-retroperitoneal approaches, without visualisation on a video-screen.

Surgical technique

After positioning of the bowl-prepared patient, either on the left side (for upper thoracic intervention) or on the right side (for the thoracolumbar junction and lumbar spine), the surgeon stands at the back of the patient (Fig. 1B). Only one assistant is necessary on the opposite side for all the described procedures; however, with a highly trained scrub nurse, these interventions can be carried out by just two people, and the presence of the assistant is not necessary. No double-lung intubation or other specific anesthesiological monitoring is needed. The patient is ventilated even on the side of the operating field. In all our operations, blood saving techniques were used, i.e., cell saver, controlled hypotension with a mean arterial blood pressure of approximately 80–75 mm Hg and the acceptance of a hematocrit level down as low as 20%. Prior to surgery, all patients received a single-dose antibiotic with a second-generation cephalosporine. In cases of neurology, steroids were given according to the NASCI III protocol [2].

Mini-thoracotomy

The thoracic spine was approached either from the right or the left side, independent of the pathology, but depending on the level of the affected vertebra. In cases of burst fractures or tumor between T4 and T8, reconstruction of the anterior column was done from the right side. The thoracolumbar junction was reached by a left-

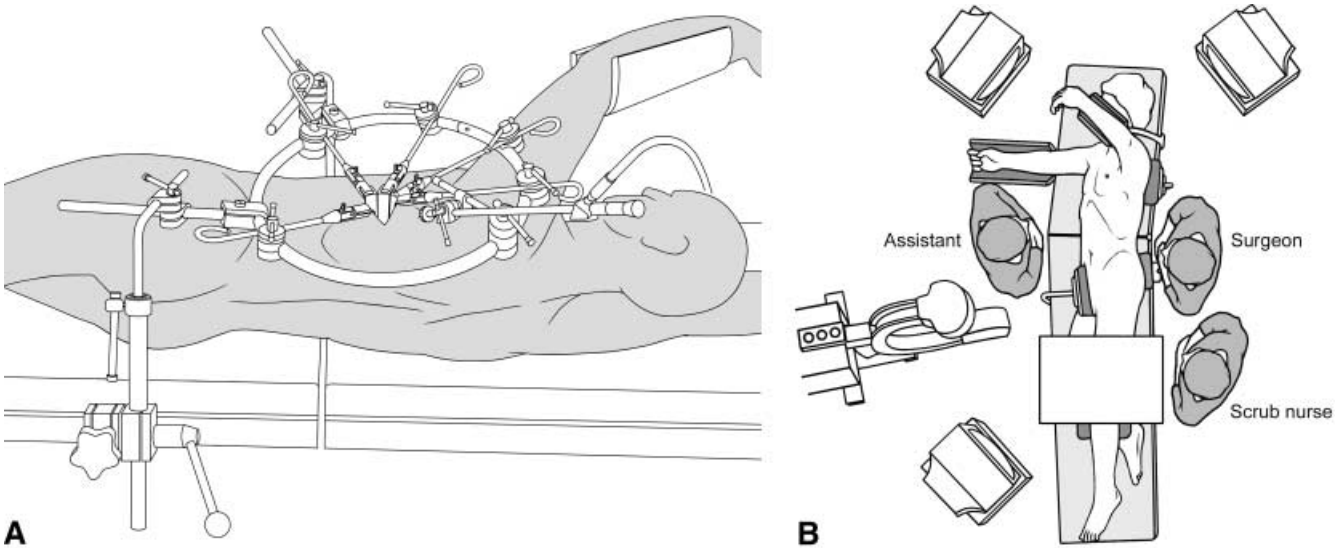

Fig. 1 **A** The SynFrame mounted onto the table in an approach to the upper thoracic spine. The patient is in a left-sided position. The thoracoscope is mounted onto the ring by a special clamp and enters the thorax by a separate incision. **B** Set-up for an open, but minimal invasive, reconstruction. The surgeon stands at the back of the patient, the assistant in front of him or her and the scrub nurse at the patient's feet

Fig. 2 Detail of a blade retractor clicked onto the ring. With the help of the lever-arm of the hexagonal screwdriver, the blade can be tilted in the sagittal plane after the blade length and the position on the ring has been chosen

Fig. 3 Specially designed fiberoptic clamp

side mini-thoracotomy, which allowed a retroperitoneal approach down to the level of L2 through a minimal incision of the diaphragm. Following the positioning of the patient on either the right or left lateral side using a radiolucent table, an image intensifier was used for the localisation of the affected vertebra. After making a skin incision of 4–6 cm, the overlying muscles were dissected bluntly and, following the opening of the thoracic cavity, the lung was identified. Disconnection from the ventilation for a short time made it possible to create the necessary space over the spine by pushing the lung, which otherwise lies over the operating field, to the side. The lung tissue was covered with a surgical towel and the retractors were placed onto the ring and adjusted to the requirements of the surgeons. Thereafter, the ventilator was connected again and the lung was ventilated, including the one on the side of the intervention. By a separate incision, the thoracoscope was installed using a trocar of 11.5 mm in diameter. This incision was used subsequently for the chest tube, which stayed in place for approximately 1–2 days after surgery. The operating field was illuminated by the thoracoscope, and the procedure for the reconstruction of the anterior column could then be started. The adjustable retractors were used in the dissection procedure, i.e., of the diaphragm, with the help of the lever arm of the hexagonal screwdriver.

Retroperitoneal mini-approach

Pathologies affecting the spine below L2 have been approached through a minimal retroperitonal access from the left side. The level of the affected vertebra was identified by an image intensifier, and projection to the skin was marked laterally on the flank. After fixing the SynFrame to the table, surgery started with a skin incision of 4–6 cm. The oblique external and internal fascia, together with their corresponding muscles, were divided along their fibers. After penetrating the transversus abdominis fascia and muscle, the retroperitoneal space was reached, allowing a blunt dissection of the peritoneal sac from the transversus muscle fascia. In some cases, the ureter could be identified, and was pushed away together with the visceral peritoneum. The blunt dissection was done either by finger or with a wet sponge mounted on a stick, until the psoas muscle was reached. This "virtual" space was kept open with properly placed retractors mounted onto the ring, which were easily adjustable during the surgery. The goal was to reach the lumbar spine without compromising the major soft tissue. Therefore, the psoas muscle was mobilized at least in part and pushed backwards to reach the lateral aspect of the vertebra. Tilting the table to the side of the surgeon eased the access procedures. In cases of very athletic patients, the psoas muscle had to be split along its fibers before reaching the lateral surface of the vertebra, since the excessive size of the muscle did not allow a direct lateral access to the vertebra. During the blunt dissection, care was taken to preserve the ilio-hypogastric/ilio-inguinal nerves, which may cross the surgical field.

Reconstruction of the anterior column

After exposing the spine laterally by a mini-thoracotomy or mini-retroperitoneal approach, the exact level of the spine was identified

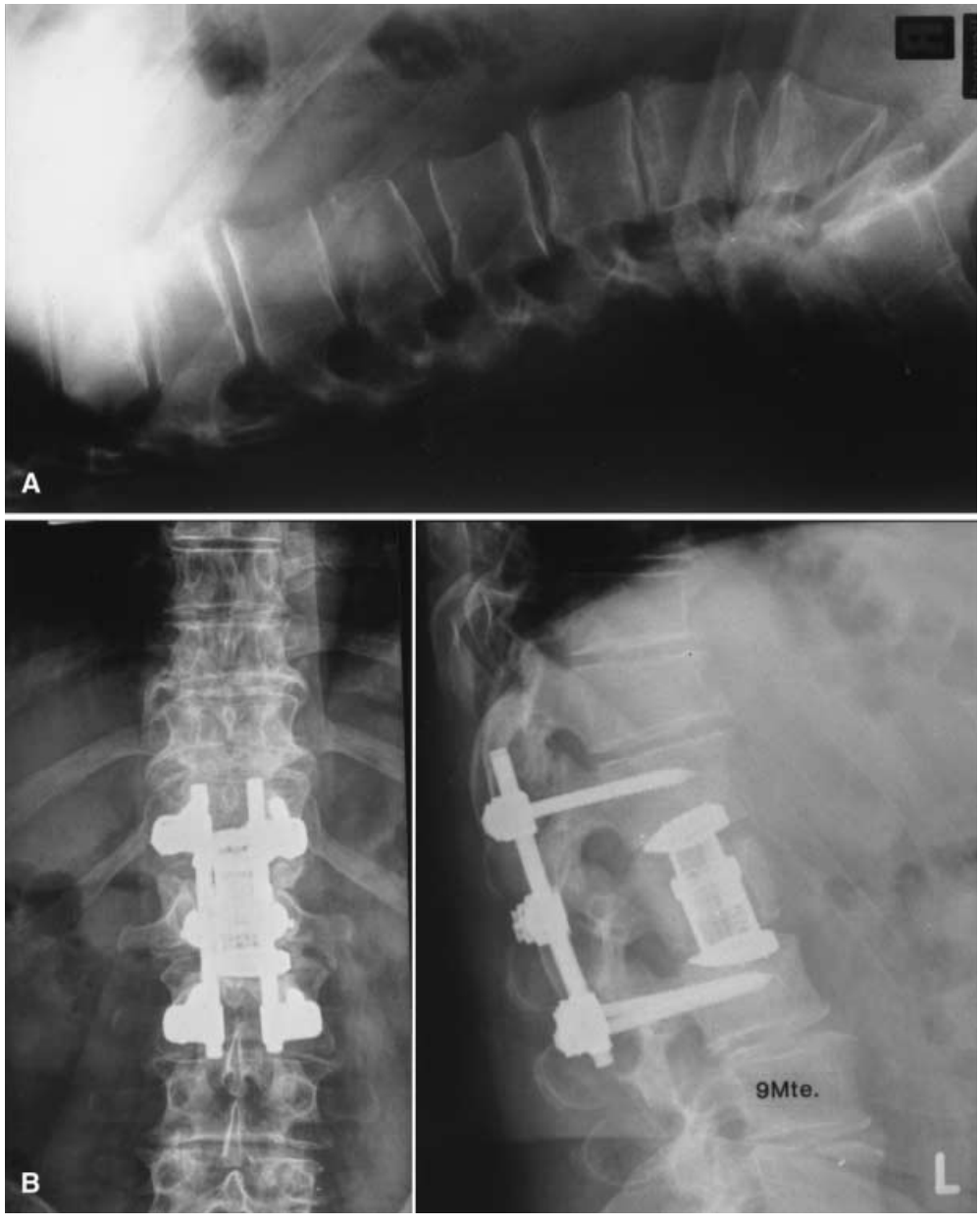

Fig. 4A,B Expandable Synex cage for the reconstruction of the anterior column. **A** Complete burst fracture. **B** Nine months after dorsal instrumentation and anterior reconstruction using a Synex cage

by an image intensifier and the adjacent disc spaces were marked with K-wires. Using these markers, it is possible to recognize the anterior longitudinal ligament as well as the spinal canal. In most cases, the overlying segmental vessels of the affected vertebra had to be clipped. The branches of the sympathetic chains were identified and, if possible, preserved. The preparation of the spine began from the disc spaces, which were cut by a knife specially manufactured for this purpose (A. Bott AG, Zurich, Switzerland). After removal of the disk, the corresponding endplate was cleaned using specially designed curettes (Synthes Spine, USA), without penetrating it. Using long osteotomes and rongeurs (Synthes Spine, USA) the vertebral body was removed under special care to leave the anterior longitudinal ligament intact. In cases with spinal canal obstruction, clearance was performed and the debris was removed from the canal. The reconstruction was completed using autologous iliac bone graft, allografts like femoral rings and iliac crests (Tutoplast, Neutromedics, Germany) as well as cages (Synex, Stratec Medical, Switzerland, also available from Mathys Medical Ltd, Switzerland) for interbody fusion (Table 1 and Fig. 4). In the six cases of metastasis to the spine, reconstruction of the anterior column was performed either using expandable cages (*n*=4) or steel plates filled with acrylic cement.

Results

Data of the 65 patients with minimal invasive spine surgery to the anterior column were collected prospectively. Twenty-five out of the 55 patients with traumatic spine injuries had additional, in some cases multiple, injuries to the head (*n*=10), thorax (*n*=9), pelvis (*n*=4) and extremities (*n*=12). Traumatic injury to the spine was classified according to Magerl et al. [11]. Thirty-four patients had an A-type, 14 patients a B-type and 7 patients a C-type fracture. There were nine fractures located on the thoracic spine (T6–T11), 35 injuries on the thoracolumbar junction (T12–L1) and 11 fractures on the lumbar spine (L2–L4). Four patients needed revisions for pseudo-arthrosis and six patients had metastatic destruction of a single vertebra in the thoracic or lumbar spine.

Twenty-nine out of the 65 patients were stabilised from posterior using the USS prior to the anterior intervention. A right-sided mini-thoracotomy was performed in eight patients to reach the middle part of the thoracic spine (T6–T8). A left sided mini-thoracotomy was chosen in 50 patients to access the thoracolumbar junction (T10–L2) and a mini-retroperitoneal approach in seven patients for intervention on the lumbar spine. In 11 patients, spinal clearance was performed from anterior via mini-thoracotomy or retroperitoneal mini approaches. Autologous tricortical iliac crest was used in 11 patients (2 thoracic, 7 thoracolumbar, 2 lumbar), autologous spongiosa in 12 patients (2 thoracic, 9 thoracolumbar, 1 lumbar), femur allografts in 2 patients and iliac crest allografts in 2 patients (Table 1). Expandable cages (Synex) for reconstruction of the anterior column were implanted 38 times (8 thoracic, 19 thoracolumbar and 10 lumbar). The cages were filled with spongiosa from the corporectomy or, as performed in seven cases, with additional autologous spongiosa taken from the iliac crest. Additional anterior instrumentation using the Ventrofix was applied in 31 patients.

The operating time (OT) was recorded from the incision to the closure time. It has to be stressed that in these data the learning period is included. The mean overall OT in all fracture cases was 170 min (range 90–295 min), but the times varied depending on the magnitude of the intervention. For a left-sided mini-thoracotomy (*n*=42), the average OT was 141 min. In combination with spinal clearance and harvesting iliac crest bone graft, the OT lengthened to 167 min. A right-sided mini-thoracotomy (*n*=7) without spinal clearance and without additional bone grafting from the iliac crest was completed in 152 min, whereas in cases with a spinal clearance, approximately an additional 60 min were needed and another 20 min for harvesting the bone graft from the iliac crest. For the mini-retroperitoneal approach (*n*=6) the mean OT was 165 min with spinal clearance and 191 min with iliac crest bone graft as well. In tumor cases (*n*=6) the intervention lasted 112 min on average, which extended to 153 min when spinal clearance was necessary. In cases of pseudo-arthrosis (*n*=4) the OT was 183 min including iliac bone grafting.

The overall mean blood loss in all cases for the anterior procedure was 912 ml. For patients undergoing spinal clearance (*n*=11), the blood loss ranged from 300 ml to 5000 ml (average 1716 ml). Only seven patients out of 65 needed blood transfusions.

There were no intra- or postoperative complications related to the minimal access; in particular, there were no vascular or visceral complications. One patient with multiple metastasis died intraoperatively due to an acute thromboembolic complication.

Four cases of mild postoperative ileus appeared, but they resolved spontaneously or by conservative means. After surgery, all patients showed minor pain at the site of the intervention, which disappeared after some days. None of the patients developed intercostal neuralgia or post-thoracotomy pain syndromes.

Neither postoperative wound infection nor deep venous thrombosis occurred. Patients with isolated spinal pathology were discharged from the hospital after an average of 13 days (range 2–30 days), while patients with additional injuries to the trunk or extremities remained for an average of 24 days (range 2–86 days).

Discussion

Minimal invasive spine surgery was introduced in the early 1990s as an experimental procedure [19]. The first results of endoscopic spine surgery clearly demonstrated the benefits of these new techniques in terms of reduced surgical trauma and reduced blood loss, with an evident decrease of blood transfusion, less pain at the site of the operation as well as an improved postoperative respiratory function [3, 4, 15, 18, 19, 20].

At the beginning of this new era of spine surgery, the main efforts towards minimal invasive access to the spine were directed towards performing all interventions by endoscopic techniques using a scope transmitting the images on a screen without a direct three-dimensional visualisation of the operative field. A number of publications appeared describing endoscopic surgery to the thoracic and lumbar spine, under a variety of names, such as minimal invasive, lesser invasive, video-assisted thoracoscopic, laparoscopic or retroperitoneoscopic spinal surgery [3, 4, 10, 11, 13, 14, 15, 16, 18, 19, 20].

However, the purpose of minimal invasive surgery is not a simple reduction in the size of the skin incision, but rather reducing to a minimum the physical trauma inflicted on the patient, while achieving maximum therapeutic result [8]. Keeping this statement in mind, endoscopic spine interventions do not necessarily achieve the mentioned goals of minimal invasive surgery. These minimal access procedures may be unfamiliar to the surgeon and may result in an overextended operation time compared to open procedures on the spine. The endoscopic views are two-dimensional, and may cause disorientation in relation to the anatomical topography due to the magnification and the lack of physical verification by the surgeon. Furthermore, the images of the operating field may appear distorted on the video screen. Taken together, these factors may lead to serious complications as reported [12, 16] and endoscopic interventions, even performed through small incisions, may become even more harmful to the patient.

These may be the reasons why the pendulum that swung towards total endoscopic spine surgery in the 1990s [4, 12, 14, 16, 20] is now swinging back in favor of open, but still less invasive, procedures. Mayer has published a remarkable work about retroperitoneal and transperitoneal approaches using a self-holding spreader frame [13]. He showed that, with his method of open but minimal invasive procedure to the lumbar spine, a spinal fusion can be achieved without serious complications, as reported by others using laparoscopic-based techniques [12, 16]. Recently, similar approaches and results have been reported by DeWald et al. [6].

Although good results have been obtained using the thoracoscopic approach to the spine [3, 19], similar problems with the endoscopic access technology as described for the lumbar spine have been encountered. Therefore, an open, but still minimal invasive, procedure to the thoracic and lumbar spine would be of advantage. A direct visualisation would be helpful for the preparation of vessels and other tissues, for performing a corporectomy and/or for spinal clearance. Furthermore, the reconstruction procedure in the anterior part of the spine as well as the instrumentation would be more familiar to the surgeon. However, such an access technology requires specially designed retractor systems. Mayer modified existing retractor systems to the specific needs of anterior lumbar interbody fusion, and the system used nowadays may be sufficient for these purposes [13]. However, a universal approach to the spine requires another, customised, tool, which has been achieved with the development of SynFrame, a retractor system that can be used at almost every part of the spine, for either anterior or posterior approaches [1].

In this study, we have shown that minimal invasive but open access to the anterior part of the thoracic and lumbar spine can be used in cases of trauma, pseudo-arthrosis and tumors. Our results clearly demonstrate that this technique is safe and easy to learn. So far, we have not experienced serious complications regarding the access as described in other studies using a classical open approach, such as rates of postoperative paraplegia, vessel laceration, and infections of up to 11.5% [7]. Furthermore, we believe that the described new access technology has additional advantages over the “pure” endoscopic techniques [3, 12, 16, 18] in terms of a reduced complication rate, shorter operation time and easier management of possible complications.

The retractor system SynFrame, which is fixed to the table, enables surgeons to operate in a way they are used to from performing open access procedures. It allows them to operate under direct vision, but still being able to use the endoscope with optimal illumination of the operating field. One of many advantages of this system is evident, in particular, in use at the lumbar-sacral junction in terms of the minimal access, feasibility of the minimal surgical intervention, and management of complications [1]. Compared to other technologies for minimal access to the spine [3, 13, 15], the described method using the Synframe retractor system has the advantage of a permanent, stable operation field. Furthermore, the choice of different retractors, including even specially designed Hohmann retractors, offers an immense flexibility to the surgeon [1].

In contrast to our former set-up for spine interventions, which engaged two surgeons and up to two assistants, a single surgeon can perform these operative interventions alone, and actually needs only the scrub nurse for assistance. There is no need for a “cameraman” handling the endoscope as described for thoracoscopic or laparoscopic spine surgery [19]. The endoscope is fixed to the ring, and necessary adjustments can be made directly by the surgeon.

A major concern to many spine surgeons is the time required in theater to perform minimal invasive spine surgery. Depending on the magnitude of the intervention, we demonstrated in this study that the overall OT was 170 min. Comparing our results with ones of other studies using a “pure” endoscopic approach for reconstruction of the anterior column in similar patients, our approach is considerably less time consuming [3, 19]. Furthermore. it must be borne in mind that the OT of this series was counted from the introduction of this new access technology. Due to the learning curve, the OT for these types of intervention could be further diminished to approximately 100 min.

Interestingly, blood transfusions have been drastically reduced in our division, since the introduction of the new

access technologies. Altogether, only seven patients needed blood transfusions during their spinal intervention, which is a reduction of approximately 70% compared to the previous open procedures (unpublished data, T. Kossmann). Our registered blood loss was comparable to other studies of endoscopic-based reconstructions of the anterior column [3]. The overall reduction of blood loss in our study as well in others [3, 4, 6, 10, 12, 15, 19] might be due to the fact that this kind of surgery requires precise surgical techniques to avoid loss of vision during surgery.

As described in other studies using minimal invasive techniques [3, 4, 15, 18, 19, 20], none of our patients complained about long lasting pain at the access site. Furthermore, we did not encounter any intercostal neuralgia or any complaints about post-thoracotomy pain as described for open procedures [5, 9].

The described method is economic, not only in terms of human resources, but also in terms of the cost of investing in endoscopic instruments and disposable materials. For instance, in laparoscopic or retroperitoneoscopic approaches to the lumbar spine, specially designed, expensive disposable trocars must be used to guarantee the pneumoperitoneum [15, 18, 19]. In contrast the SynFrame system has no disposable items, and all parts of the system are autoclavable, which is another major advantage of this technique.

Conclusions

Our results so far indicate that this technology for minimal invasive access to the spine is safe and easy to use. This makes the described method with the universal use of the SynFrame not only an alternative to thoracoscopic or laparoscopic procedures, but it also overcomes the disadvantages of endoscopic spine surgery as previously described. The ring retractor system allows minimal open surgery to the spine by carrying different devices as well as the fiberoptic illuminator and endoscope, providing an excellent visualisation of the operating field, and therefore this novel access technology can be used in all pathologies affecting the spine.

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