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ORIGINAL ARTICLE

The direct anterior approach to the thoracolumbar junction: an anatomical feasibility study

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Abstract
Introduction The thoracolumbar junction (TJ) is traditionally exposed by lateral or posterior approaches. This usually requires splitting of the diaphragm, or extensile removal of the posterior elements. A circumferential exposure (i.e. simultaneous anterior and bilateral exposure) of the vertebral body is not possible. Direct anterior access would allow circumferential exposure of the vertebral body, with adjacent disc levels, and would avoid splitting the diaphragm or extensive removal of the posterior bony structures.
Materials and methods Twelve Thiel cadavers (8 f/4 m) were dissected to access T12 or L1 via a midline laparotomy. Supra- and infragastric laparatomy techniques were investigated. Six cadavers were used to reach T12 through the lesser omentum, six to reach L1 through the greater omentum.
Results T12 after bluntly dissecting the lesser omentum, the lesser gastric curvature and the caudate lobe of the liver were utilised as landmarks. A small retroperitoneal incision was performed to mobilise the aorta allowing exposure of the T12 vertebra and its adjacent discs. Discectomy, corpectomy and insertion of an anterior column support were possible. The L1 level can be reached through the greater omentum by mobilising the pancreas as a single retroperitoneal structure, leaving the aorta and celiac trunk as landmarks. Retraction of the great vessels is necessary to expose L1 with its adjacent discs. Implantation of an anterior column support was possible utilising this approach.
Conclusion Direct anterior access to the TJ is feasible in a reproducible manner. This approach would avoid splitting the diaphragm, or dissection of the erector spinae muscles, and is likely to be less invasive than standard lateral or posterior approaches. This technique may offer a significant time reduction to surgery, especially in exposing the spine. Anterior column support can easily be performed, offering a better avoidance of kyphotic deformities.

Keywords Anterior access · Thoracolumbar junction · Anatomy · Anterior spine surgery

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Introduction

The thoracolumbar junction (TJ) has always been a region of high interest for spinal surgeons.

The unique positioning where there is a transition from the thoracic kyphosis to lumbar lordosis leads to a very sensitive balance of biomechanical demands. This could easily be disturbed by either traumatic or oncological pathologies [1–3]. The support of the anterior column, in order to restore sagittal balance, seems to be the paramount issue in the decision making for treatment of pathologies at this level [4]. Hodgson and Stock [5] have already described the anterior approach to the thoracolumbar spine in cases of Pott's disease in 1956. This extended approach led to an excellent exposure of the thoracolumbar junction,

Table 1 Summary of the specific cadaver features

Number	Sex	Height	Weight	Age	Supragastric approach	Infragastric approach	Comments
1	F	150	35	88	T12		
2	F	156	59	67	T12		
3	M	158	38	83		L1	Transomental
4	F	154	45	89	T12		
5	F	161	53	91		L1	Transomental
6	F	153	45	90	T12		
7	M	162	51	87		L1	L2 osseous intervertebral disc, omentum mobilisation
8	M	161	49	85		L1	Omentum mobilisation
9	F	152	46	73	T12		Abdominal surgery
10	F	161	61	87		L1	Omentum mobilisation
11	M	163	60	82		L1	Omentum mobilisation
12	F	155	63	89	T12		Abdominal surgery

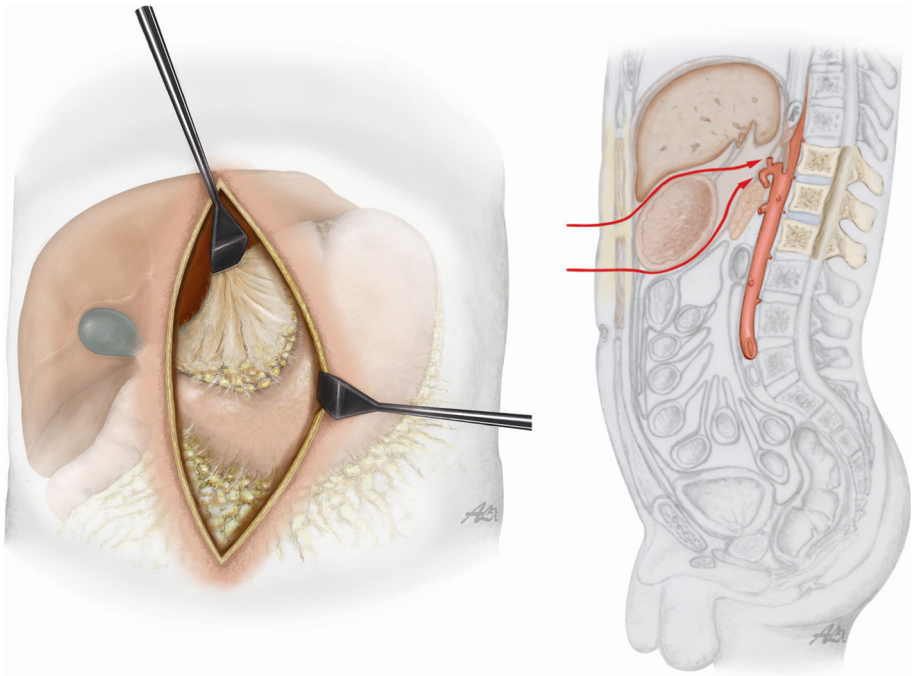

Fig. 1 *Left* incision of the peritoneum, showing the right liver lobe on the left and the small curvature of the stomach on the right hand side. *Right* strategic planning for both approaches to the thoraco-lumbar junction. Supragastric access through the lesser omentum to reach T12. Infragastric dissection to reach L1

but required a thoracotomy, with detachment of the diaphragm, and the sacrifice of adjacent ribs when necessary. The access-related morbidity was high, leading to further developments including mini-open, laparoscopic or thoracoscopic approaches [6–15] to improve clinical outcomes. However, not one of these methods resulted in a circumferential exposure of the vertebral body of the thoracolumbar junction.

The aim of this study was to create an easily reproducible anterior approach which would allow circumferential exposure to the thoracolumbar junction in the supine position, whilst identifying possible pitfalls to the technique.

Materials and methods

Twelve cadavers embalmed according to Thiel [16] were used in this study. Two specimens had had abdominal surgery previously. The specific features of all cadavers are summarised in Table 1. All cadavers were placed in the supine position for dissection. The standard approach to the thoraco-lumbar junction utilised was a midline upper laparotomy (Fig. 1). After dissecting the subcutaneous layer and opening the peritoneum, two main strategies were developed:

To reach T12 with its adjacent intervertebral discs, a supragastric dissection through the lesser omentum was

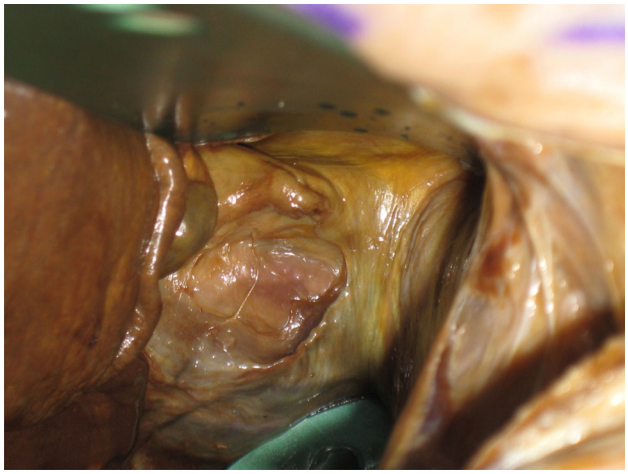

Fig. 2 After blunt dissection of the lesser omentum, the caudate liver lobe (*left*) and the small gastric curvature (*right*) could be identified as anatomical landmarks. Exposure of the retroperitoneum

chosen. Accordingly, the exposure of L1 was performed by dissecting or mobilising the greater omentum infragastrically (Fig. 1). Six cadavers were used for each approach.

Both dissections had to be as minimally traumatic as possible by following anatomical clefts and spaces whenever possible. In addition, standardised and reproducible steps were identified and developed to facilitate the expected learning curve with any new technique.

Results

Exposure of T12

After performing the laparotomy and opening the peritoneum, the lesser omentum was bluntly dissected. The anatomical landmarks identified to allow access to the spine were the caudate lobe of the liver on the right and superior borders, whilst the lesser gastric curvature defined the left and inferior borders (Fig. 2) of the approach. This is similar to the boundaries of the lesser sac. A retractor system was inserted to allow good visualisation of the retroperitoneal area, which was opened to expose the aorta and the celiac trunk (Fig. 3). It is necessary to mobilise approximately 10 cm of the aorta to allow its retraction to the right side without damaging other vascular structures, especially the celiac trunk. This approach produced a circumferential exposure of T12 with its adjacent intervertebral discs. In addition to this, one segmental artery must be sacrificed to expose the vertebral body. After a superior and inferior discectomy, the vertebral body was completely removed piecemeal to expose the spinal cord (Fig. 4). For didactic reasons, an expandable cage was introduced, and finally the cadaver was opened to verify the level of exposure (Fig. 5).

Exposure of L1

This is more technically demanding than the supragastric approach to the thoraco-lumbar junction because of the anatomical landmarks encountered. The abdomen and peritoneum is opened in a similar way to the previous approach, and the greater omentum is identified. In two cases, the omentum was dissected to reach the infragastric space. In the remaining four cases, the omentum was mobilised with the stomach cranially to reduce the access morbidity (Table 1). The next step performed to reach the thoraco-lumbar junction, was caudal mobilisation of the pancreas and its adjacent soft-tissues. Once again, a segment of the aorta was exposed and mobilised to the right side after ligating one segmental artery. Following this, the intervertebral discs were removed and the vertebral body circumferentially exposed (Figs. 6, 7). After the piecemeal vertebrectomy, the spinal cord was identified and a distractable vertebral body replacement installed. The correct positioning was once again confirmed after complete removal of all intestinal organs (Fig. 8).

Discussion

When reconstructing the spine in the thoracolumbar junction, anterior column support is necessary to reduce strain forces across the posterior structures and prevent postoperative kyphotic deformity [4]. Hodgson and Stock [5] treated 48 patients with Pott's disease with anterior spinal fusion. Despite good clinical outcomes, the radical dissection necessary to reach the area of interest produced a high percentage of complications and associated morbidity. Since then, different approach strategies were established to decrease access related morbidity. In general, three main surgical techniques can be found in the literature: strictly posterior procedures, anterolateral exposures and endoscopic techniques.

The posterior approach requires prone positioning of the patient and a standard midline incision with exposure of the posterior elements. Despite good clinical results with regard to reduction and neurological outcome, the exposure of the affected vertebra is limited. In some instances, therefore, it might be necessary to sacrifice nerve roots or intercostal nerves to enable a better exposure [6, 7]. Once adequate resection of the vertebral body has been performed, the thoracolumbar junction is often fused with long constructs. However, this can lead to loss of flexibility and movement, and result in altered biomechanics with the potential development of adjacent level disc disease. Furthermore, the extensive removal of the posterior elements and associated corpectomy, especially in tumour cases, can result in massive blood loss with the need for transfusion.

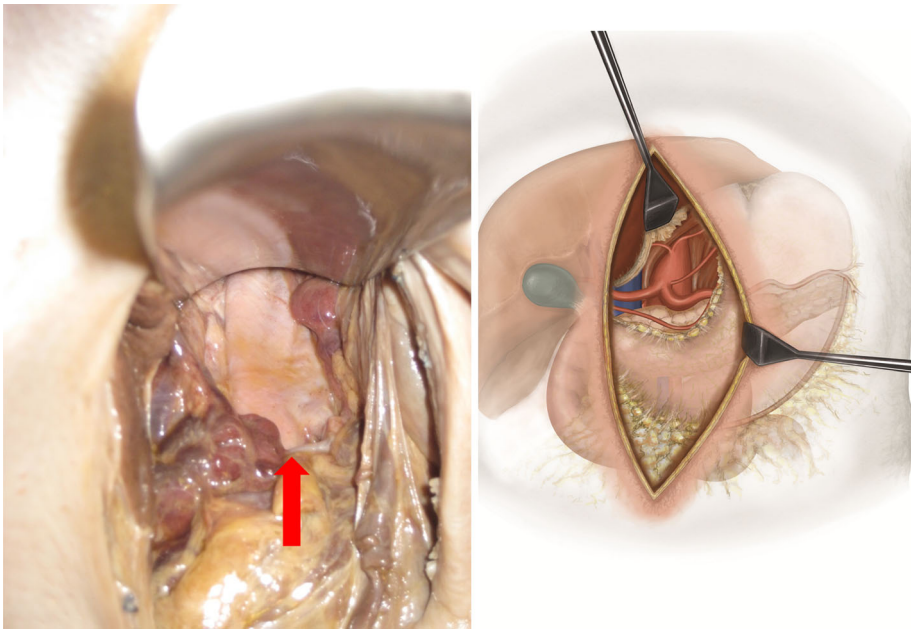

Fig. 3 *Left* retroperitoneal dissection, identification of the aorta and celiac trunk (*red arrow*). *Right* schematic overview of the retroperitoneal zone with the aorta and celiac trunk

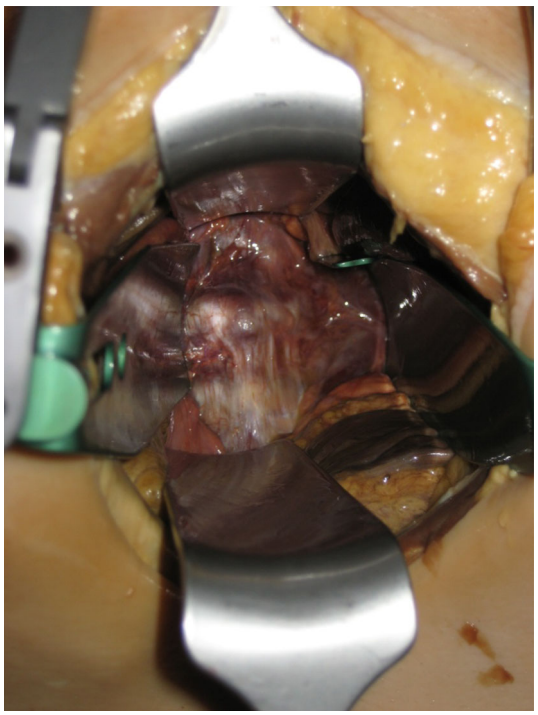

Fig. 4 After vessel retraction, exposure of T12 with adjacent discs was performed

Minimal invasive posterior surgical options might cause less complications, but they do have a significant learning curve [8].

It must be remembered that in addition to piecemeal removal of the vertebral body in posterior only procedures, enbloc resections can be performed [9, 10]. A titanium cage replaces the removed vertebral body. Normally, this kind of surgery sacrifices at least the rib heads, but may include the neck of the ribs at the affected level. It might also be necessary to ligate one or more intercostal nerves to allow adequate surgical access to the vertebral body. All these can lead to similar approach related problems such as intractable post-operative pain.

Another option described to access the thoraco-lumbar junction is the antero-lateral approach [11, 12]. The patient is normally placed in a true lateral position. It is necessary to provide single lung ventilation to open the thoracic cavity, which might compromise the patient's respiratory function during surgery. Ribs may need to be sacrificed as well, and this can be associated with post-operative morbidity. A circumferential exposure of the affected vertebral body is not possible, even if a retropleural access is chosen. If the affected level is L1, a detachment of the diaphragm is needed for exposure. Diaphragmatic hernias and accidental injuries to abdominal organs, especially splenic injuries, might result from this approach [12]. Access from the right side is more difficult due to the liver, which limits revision surgery options.

In order to reduce the access morbidity even more, endoscopic techniques were introduced [13–15], but this might require an independent access surgeon depending on skill levels. If a transthoracic approach is chosen, single lung ventilation is needed and the diaphragm is split where necessary. These techniques have a substantial learning curve and it is not possible to create a circumferential exposure of the target area.

The direct anterior approach developed here in this study had two main goals: the surgical technique should be reproducible with well-described steps which a spinal

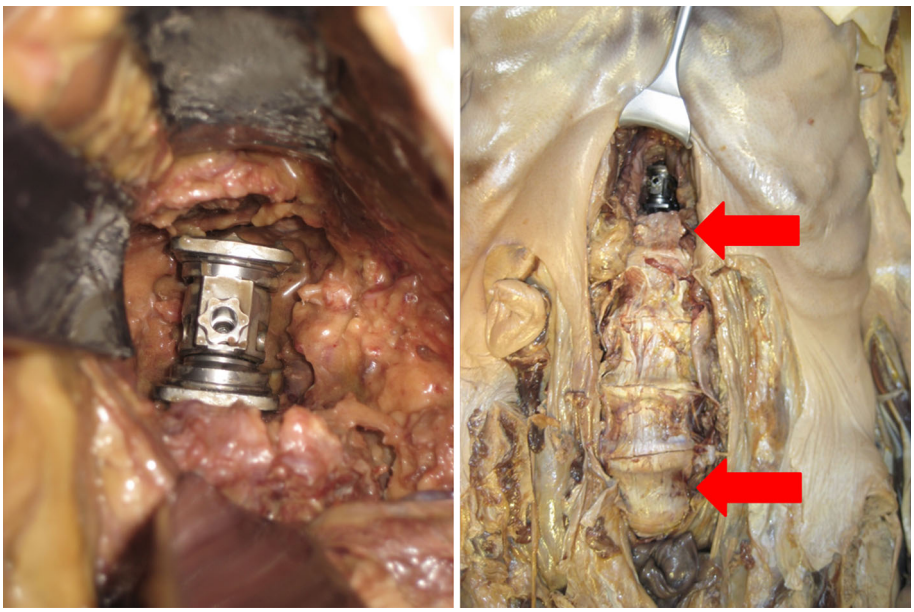

Fig. 5 Introduction of an expandable cage and verification of level (*arrows marking* L1 and L5)

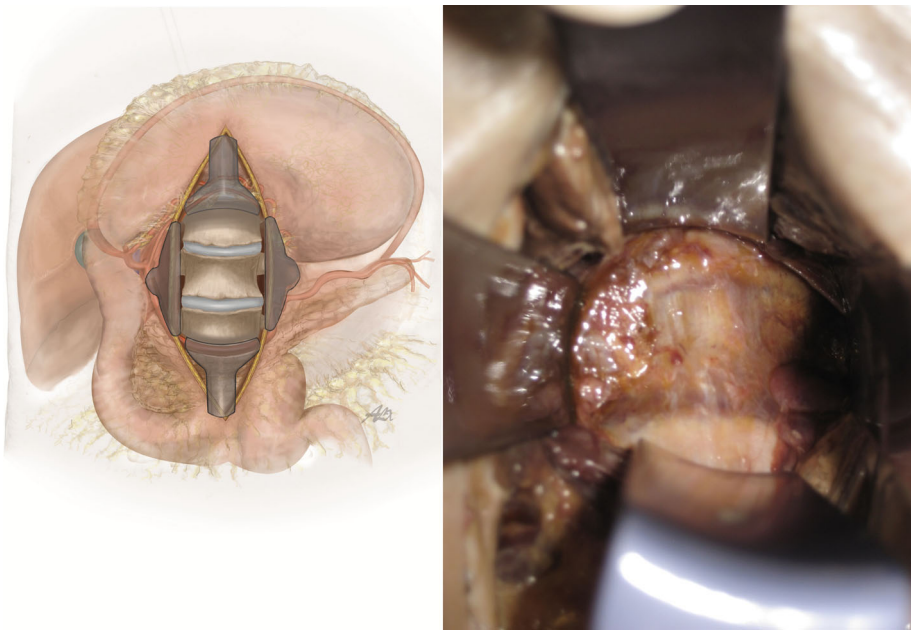

Fig. 6 Exposure of L1 after the infragastric dissection. *Left* illustration of vessel and organ retraction. *Right* in-situ picture of L1 with adjacent intervertebral disc spaces

surgeon (potentially with the aid of a general or vascular surgeon) is capable of learning. Secondly circumferential exposure of the vertebral levels T12–L2 should be achieved.

It was possible to create reproducible steps to reach T12 and L1, and after a small learning curve, to simulate a reconstruction of the vertebral body. The main identified structures at risk were the aorta, the celiac trunk and pancreas. The mini-open technique avoids the gas insufflation necessary in endoscopic techniques and the opening of two body cavities. The posterior elements can be retained completely, offering a better structural integrity and potentially improving the biomechanical properties of the thoracolumbar junction post-operatively. In contrast to antero-lateral exposures, there is no need to split the diaphragm, hence avoiding the risk of pleural effusions, hernias or compromised lung function. The spinal cord and nerve roots are potentially at less surgical risk since good visualisation is guaranteed with this access. In addition, supine positioning of the patient might facilitate surgery with significant reduction of surgery time.

The biggest advantage is, as mentioned above, the circumferential exposure, offering the potential for complete corpectomy with its adjacent structures. Motion segment

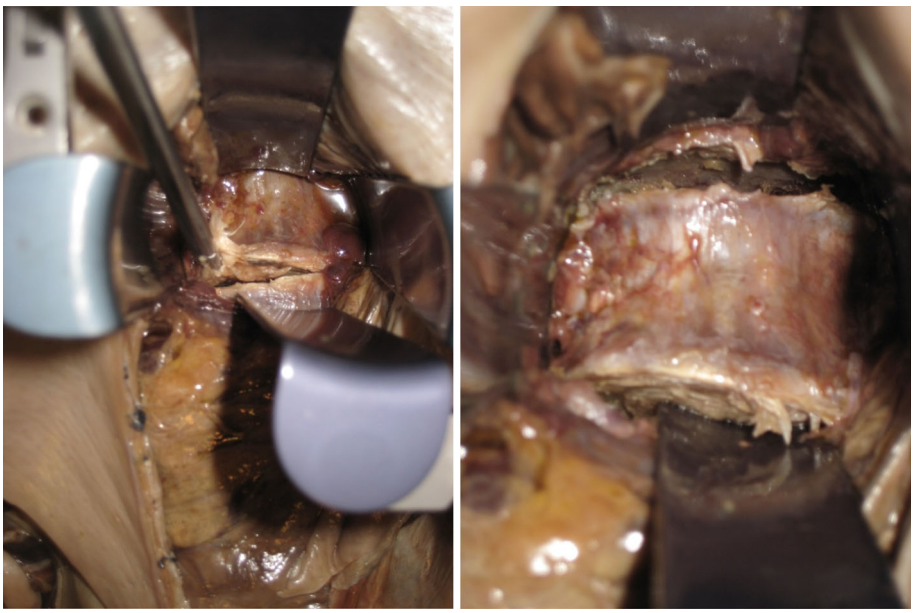

Fig. 7 Total disc removal and circumferential exposure of the L1 vertebral body

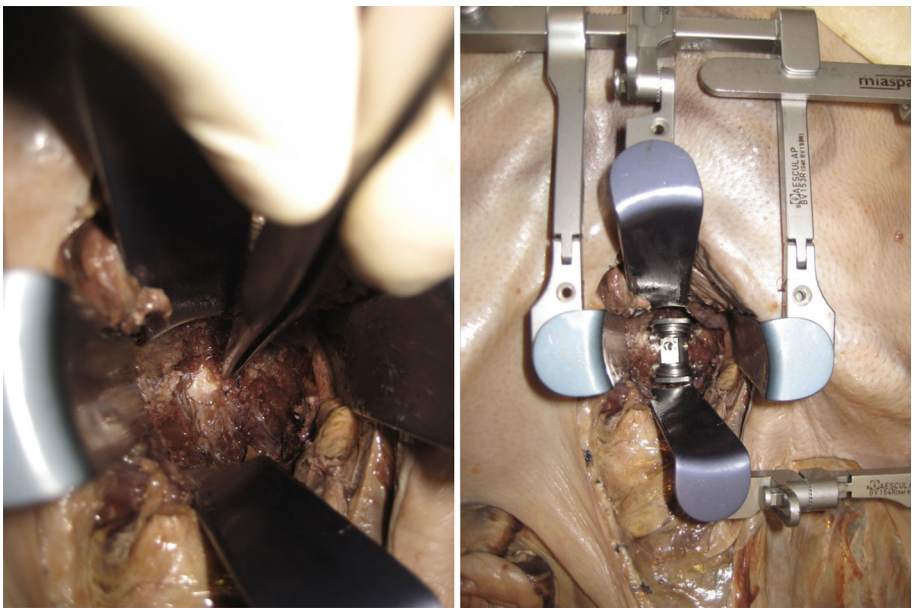

Fig. 8 *Left* identification of the spinal cord. *Right* overview after cage implantation

replacement is then possible, allowing a more anatomical reconstruction of this region of the spine. In our cadaveric exposures a single segmental artery needed to be ligated unilaterally. In a live surgical setting it may well be necessary to sacrifice segmental arteries bilaterally or over two segments—especially if developments were directed towards en-bloc removal techniques. Sacrificing two segmental arteries should not affect the blood supply of the spinal cord but nevertheless this risk would need to be carefully considered prior to surgery.

Despite the mentioned advantages, this access still has its own risks and pitfalls. Major vessels could be injured, needing immediate vascular surgery support and routine precautions for control of massive haemorrhage should be employed. The cadavers used in this study were very slim and only two had had abdominal surgery previously. This access has the potential to prove more technically demanding in obese patients, patients with hepatomegalia or even patients with previous extensive abdominal surgery. Careful patient selection should be conducted before this access is used. There is also the potential for iatrogenic injury to the pancreas, which can lead to fistulas, abscesses or peritoneal inflammation. It might also be necessary for spinal surgeons, at least during the learning curve, to enlist the help of general surgeons. Despite all this, the direct anterior approach has the potential to be a useful tool in the

treatment of patients with pathologies in the thoraco-lumbar region.

Conclusion

The direct anterior approach to the thoraco-lumbar junction has several advantages compared to the established antero-lateral and posterior exposures. The supine positioning is relatively easy to manage and less arduous when compared with prone positioning. Compared to the antero-lateral dissection, it is not necessary to split the diaphragm, hence avoiding the opening of two body cavities. The neural structures are not endangered unlike in strictly posterior procedures. All these advantages mean that the total anterior approach to the thoracolumbar junction might be an alternative for selected patients for anterior column support in the future. However, thorough knowledge of visceral and vascular structures is needed to perform this approach. This feasibility study may serve as the basis for ethics application for clinical trials.

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