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Full endoscopic surgery for thoracic pathology: an assessment of supportive evidence

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- In the last five years, surgeons have applied endoscopic transforaminal surgical techniques mastered in the lumbar spine to the treatment of thoracic pathology.
- The aim of this systematic review was to collate the available literature to determine the place and efficacy of full endoscopic approaches used in the treatment of thoracic disc prolapse and stenosis.
- An electronic literature search of PubMed, Embase, the Cochrane database and Google Scholar was performed as suggested by the Preferred Reporting Items for Systematic Review and Meta-analysis statements. Included were any full-text articles referring to full endoscopic thoracic surgical procedures in any language.
- We identified 17 patient series, one cohort study and 13 case reports with single or of up to three patients.
- Although the majority included disc pathology, 11 papers related cord compression in a proportion of cases to ossification of the ligamentum flavum or posterior longitudinal ligament. Two studies described the treatment of discitis and one reported the use of endoscopy for tumour resection.
- Where reported, excellent or good outcomes were achieved for full endoscopic procedures in a mean of 81% of patients (range 46–100%) with a complication rate of 8% (range 0–15%), comparing favourably with rates reported after open discectomy (anterior, posterolateral and thoracoscopic) or by endoscopic tubular assisted approaches. Twenty-one of the 31 author groups reported use of local anaesthesia plus sedation rather than general anaesthesia, providing 'self-neuromonitoring' by allowing patients to respond to cord and/or nerve stimuli.

Keywords: full endoscopic; thoracic discectomy; transforaminal surgery

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Introduction

It is well recognized by surgeons that interventional treatments at the thoracic level are liable to be technically difficult and demanding. Not only is surgical access to the thoracic spinal canal limited by the anatomical constraints of the rib attachments but the spinal cord at the thoracic level is particularly vulnerable to surgical intervention. The natural thoracic kyphosis flattens the dural sheath against the posterior margin of the disc and the spinal cord's mobility is limited within the canal by the denticulate ligaments. In addition, the ratio of cord diameter to that of the canal leaves little space around the cord and, at some levels, the medullary vascularization is limited.[1]

In the majority of world centres, thoracic disc pathology is still approached using direct open anterior or posterior approaches.[2] Direct access via a transthoracic approach[3] entails opening the chest cavity and, in the case of a disc prolapse, excision of significant healthy tissue before reaching the protruding fragment. Advocated for central calcified discs, the quantity of bone and disc resection will generally require vertebral fusion to prevent postoperative pain at the affected level. Even with a more minimal approach using video-assisted thoracoscopic techniques (VATS),[4,5] or mini-thoracotomy (mini TTA),[6] there remains a significant risk of complications including paralysis, paresis, pleural tear and pneumothorax.[7,8] The alternative direct posterior approaches with laminotomy and durotomy are similarly disliked by most surgeons as segmental nerve root resection may be required and the risk of cord injury is significant.[9] This leaves one of the posterolateral approaches as probably the most commonly performed choice of access to the spine, including costotransversectomy, transpedicular and lateral extracavitary techniques.[10–12] Unfortunately, in each approach, rib head or pedicular resections are required, leading potentially to intraoperative entry to the chest and postoperative pain. Access to the central areas of the disc is also limited. Overall, complications from open surgery are reported to

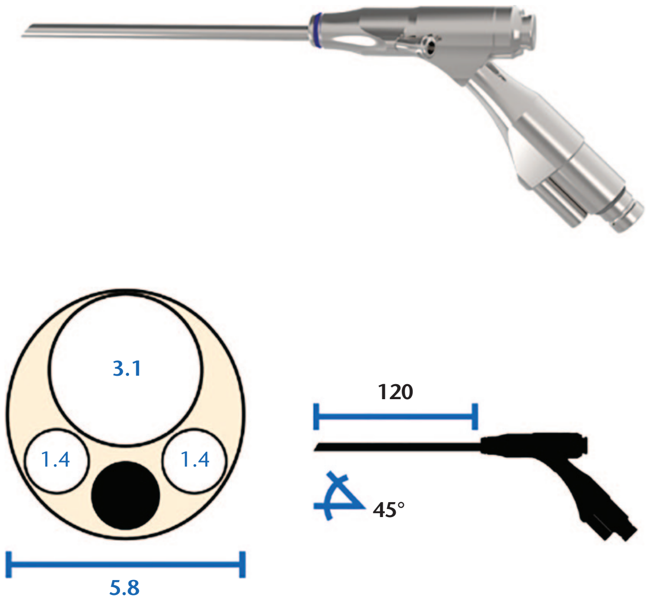

Fig. 1 Thoracic endoscope (joimax®, GmbH).

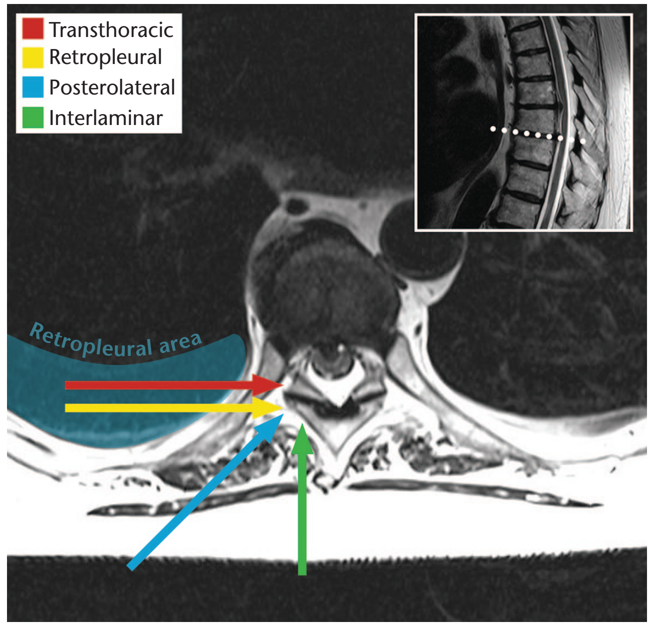

Fig. 2 Surgical approaches to the thoracic spine.

occur in excess of 25% of patients[7,13] and, for this reason, approaches minimizing operative harm are ideal.

As a separate entity from disc prolapse, spinal stenosis is relatively rare in the thoracic spine and generally occurs below the T9 vertebra. When it does occur, the stenosis is often severe and decompression is urgent as cord compromise may lead to myelopathy. Traditionally, as in the lumbar spine, a laminectomy would be offered, but surgeons have long recognized that this is associated with a significant risk of the development of postoperative kyphosis. Also, if there is associated ossification of the posterior longitudinal ligament, a thoracotomy will be required or macro-invasive circumferential decompression.[14–16] Although some attempts have been made to reduce 'invasion' by tubular decompression through large bore cannulae, these techniques have not been universally adopted.[17]

In the 1980s, surgeons recognized the potential for safe access to the spine via the Kambin triangle,[18] and this led to the development of full endoscopic instrumentation that could be coupled to high-definition video camera systems. Although initially the primary focus was on access to the lumbar spine,[19] there are now state of the art instruments suitable for use in both the neck and thoracic regions (Fig. 1).

Following initial technical notes,[20–22] there have been an increasing number of publications describing the use of full endoscopy applied to thoracic pathology and it is now timely to review the substantive evidence supporting the novel techniques described. The aims of this review are therefore to describe the most frequently adopted transforaminal and interlaminar endoscopic approaches and collate the evidence for and against the techniques and advances in technology described, contrasting outcome data with those expected after open surgery. The following full endoscopic classifications are currently recommended by the AO Spine group.[23]

1) Transforaminal endoscopic thoracic discectomy (TETD).
2) Thoracic endoscopic unilateral laminotomy for bilateral decompression (TE-ULBD).
3) Transpedicular endoscopic surgery.

Approaches and differences in full endoscopic thoracic techniques

Most commonly, either a transforaminal or interlaminar approach will be used for endoscopic access (Fig. 2).

Transforaminal technique

The anatomy at the levels T2 to T9 differs from that at the thoraco-lumbar junction due to the overlap of the rib heads, which cover approximately half of the foraminal and disc space (Fig. 3). A partial resection of the rib heads during endoscopic surgery is therefore required. At the thoracolumbar region, the anatomy is very similar to that of the lumbar spine, although careful preoperative evaluation of the retroperitoneal area should be performed to avoid approach-related complications with injury to a kidney or bowel. Optimally the patient is positioned prone with an approach from the side of main clinical symptoms and spinal pathology. The ribs are palpated through

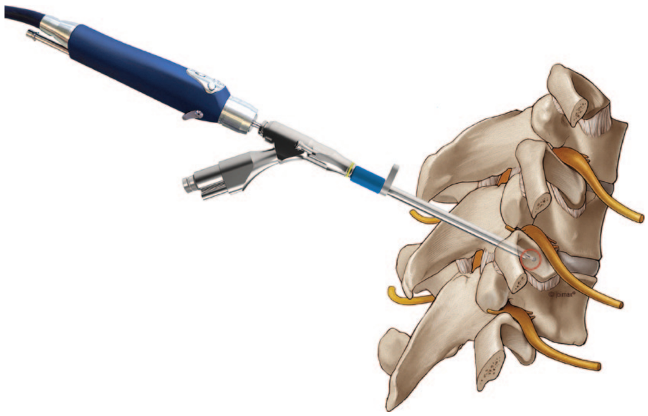

Fig. 3 Endoscopic access via the Kambin triangle.

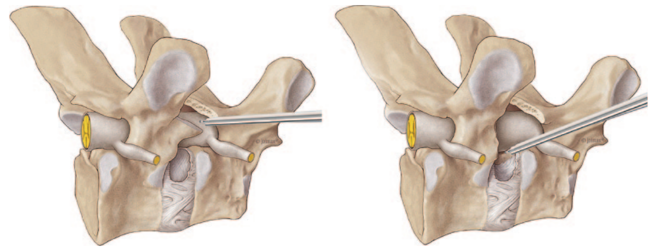

Fig. 4 Enlargement of foramen.

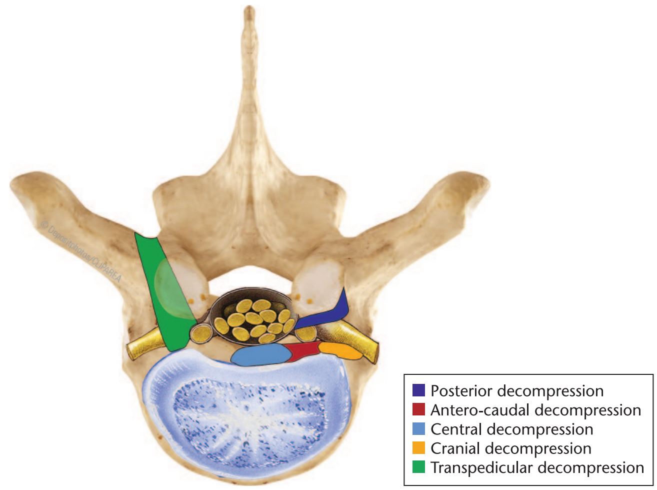

Fig. 5 Areas of endoscopic decompression.

the skin and an incision made about 5 cm lateral to the spinous process line. The angle of the access needle is 20–30 degrees in a cranio-caudal direction pointing to the lateral recess and the caudal part of the neuroforamen of the symptomatic level.

The fragility of the thoracic neural structures limits the placement of the approach tools and initial aim of these should be towards the disc. A Jamshidi needle, or pointed approach rod, is a helpful aid with puncture of the cranial part of the rib head and advancement into the disc space. Discography with methylene blue or indigo carmine is then possible and helpful to differentiate disc from other tissues. In rare cases with sequestrated disc material a transpedicular approach may be appropriate.

As a consequence of the thoracic foraminal anatomy and the relatively small size of the neuroforamina, a diamond burr should be used intraoperatively under endoscopic visual control to widen out the working space. After placing the endoscope, the epidural space, disc and lateral recess are identified. This is followed by a stepwise preparation and enlargement of the foraminal area with the aim of creating space for the endoscope and gaining mobility inside the spinal canal (Fig. 4). The next step is to identify the ventral bone structures as well as the margins of the disc. Under endoscopic view, bone and disc material are removed and anterior decompression achieved (Fig. 5). A flexible bipolar radiofrequency probe is useful to stop any epidural bleeding. After decompression and visual inspection of the decompressed nerve elements, repeatedly checking positioning with the endoscope and image intensifier, the endoscope may be removed and skin closed.

Interlaminar technique

The main differences between the interlaminar approach at the thoracic to that at lumbar levels relate to the lesser size and thickness of the laminae, the more horizontal anatomical orientation of the facet joints and the fragility of the neural structures. The thickness of the flaval ligament increases stepwise from the upper to the lower spine and the architecture limits interlaminar endoscopic techniques for posterior and lateral pathologies. Similar to open techniques, a medial pedicle resection is necessary to create enough space to avoid manipulation of the central cord.

For the posterior decompression procedures without disc resection, a large diameter endoscope (e.g. Ilessys Delta®, joimax GmbH or Vertebris stenosis®, RIWOspine GmbH) will allow a controlled resection of posterior compressive structures. Close attention is necessary as the decompressed area of the interlaminar window must not exceed the size of the working tube to avoid an uncontrolled antero-posterior movement and manipulation of the dura with potential tear. A holding arm is helpful to avoid uncontrolled pressure on the cord.

Patients are best positioned prone. The incision is about 3 cm from the midline unless contralateral decompression is needed, in which case 5 cm may be more appropriate.[24] After stepwise dilatation the endoscope is inserted. The laminae and interlaminar window are decompressed with a combination of a diamond burr and Kerrison punches.

Fig. 6 Interlaminar unilateral laminotomy for bilateral decompression.

In bilateral stenotic pathologies the ipsilateral side should be decompressed and then the contralateral side, using an 'over-the-top' technique. All areas of the spine may be reached (Fig. 6). If possible, the ligamentum flavum should be maintained intact until the bone decompression has been finished as it is used as a protection of the dura. After decompression, a radiograph will confirm the amount of decompression achieved. Anterior pathologies of the lateral recess may be addressed by interlaminar endoscopy but will require a partial medial pedicle resection. This often is possible only after facet resection.

Methods

Literature search

The following searches of the literature from 2000 to September 2020 were made:

1. A core search by computer-aided searching of Pubmed (www.ncbi.nlm.nih.gov/pubmed), Google Scholar and the Cochrane Library databases in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[25,26] "Thoracic" and "endoscopic" were identified as key search terms from an initial recent literature screen and were secondarily used in combination with "disc", "discectomy", "myelopathy" and "transforaminal" (filter Human) in turn for a full literature analysis.
2. A standard search including:
   a) personal bibliographies held by the authors.
   b) citation tracking from all papers identified by the above strategies.

Titles and abstracts meeting the inclusion criteria were screened and all full-text articles published in peer-reviewed journals independently reviewed by two of the authors (RDSG and JNAG). Papers were sought in all languages with translation to English performed if required and reference lists of each study checked for missing reports. Animal studies, biomechanical studies, purely technical notes with no quantitative outcome data and meeting presentation abstracts were excluded. Case reports were referenced and included in the data analysis.

Table 1. List of eight items of the Methodological item for non-randomized studies[27]

1	A clearly stated aim
2	Inclusion of consecutive patients
3	Prospective collection of data
4	Endpoints appropriate to the aim of the study
5	Unbiased assessment of the study endpoint
6	Follow-up period appropriate to the aim of the study
7	Loss to follow-up less than 5%
8	Prospective calculation of the study size

Quality assessment

The methodological quality of all patient series found (non-comparative studies with more than three patients) was assessed using the first eight items of the Methodological Index for Non-Randomized Studies checklist.[27] Each study was scored on eight items from 0 to 2 by two of the authors and any disagreements were referred to the third author (maximum value 16 – see Table 1: 0 = not reported, 1 = inadequate, 2 = adequate).

Data extraction

Data from each study were extracted to populate Tables 2 and 3. Patient characteristics, pathology of the thoracic disease, level(s) of surgery and factors influencing post-operative course were sought. Particular care was taken to tabulate all patient-reported outcome measures (PROMs) to allow conclusions to be drawn as to the efficacy of full endoscopic surgery.

Results

Using the primary search terms in combination with each of the secondary terms on PubMed yielded 112 results, 68 of which were unique when collated. Searching Google scholar for article titles containing the same terms in combination, published over the same period (2000–2020) yielded 56 results, 31 of which were unique. When combined, the literature searches of these two databases revealed a total of 81 full articles for review (Fig. 7). An additional 14 papers were added from personal database and bibliographies. Fifty-one were immediately excluded following abstract review. Thirteen articles were discounted on full-text review as they were primarily descriptions of open approaches or techniques using tubular devices to facilitate exposure. The year of publication of those included ranged from 2006 to 2020 with the majority having been published in the last two years. Seventeen of the studies were non-comparative

Table 2. Published patient series of Full Endoscopic treatments of thoracic disorders

	Pathology	Technique	*N* (m:f)	Age (range)	Follow-up months (range)	Anaesthesia	Op time mins (range)	Stay (days)	Excellent / Good / Fair (%)	VAS Back (Dec.%)	VAS Leg (Dec.%)	ODI (Improv.%)	JOA score (RR %)	MINORS score	Complications	Comments
Patient series																
An, 2019[28]	OLF T2:T12	IL	18 (8:10)	59 (44–77)	17 (12–24)	LA	172 ± 30	5 ± 2	77				48	13	Dural tear x 2	
Bae, 2019[29]	Disc T2:T6	TF	14 (12:2)	42 (26–69)	43 (6–120)	LA			86	68		67		11	Nil	
Bae, 2020[30]	Disc T2:L1	TF	92 (57:35)	49	38	LA			90	79		81		11	Motor weakness x 1; Paraesthesia x 3; Recurrence x 2; Revision x 1	Hol:YAG laser
Cheng, 2020[31]	OLF (5), Disc (5), OPLL (2)	IL	12 (6:6)	55 (27–73)	12	LA	85 (70–120)	4 (3–6)	92				74	10	Dural tear x 1; Transient paralysis x 1	
Choi, 2010[20]	Disc T2:T12	TF	14 (6:8)	48 (21–75)	60 (15–89)	LA	61	1–2		54	57	58		7	Secondary surgery x 2	
Guo, 2019[32]	Disc T9:12	TF	6 (4:2)		13 (11–14)	LA	48 (40–60)		100	76	97	29	33	9	Nil	
Lee H, 2006[33]	Disc T2:T12	TF	8 (3:5)	51 (31–75)	27 (12–48)	LA	55	2.5 (1–6)				51		11		Hol:YAG laser
Lee S, 2018[34]	Disc	TF	87 (51:36)	(21–89)	10 (1–56)	LA				71		69			Recurrence x 2; Recovered paraesthesia x 3	
Li X, 2020[24]	OLF	IL	30 (17:13)	61 (44–84)	21	LA	167 (100–240)		46				54	11	Dural tear x 2	
Li Z, 2020[35]	Disc (12), stenosis (4) T3:T12	TF	16 (12:4)	54	12	LA	48 (45–60)			77	93	59	72	10	Intercostal neuralgia x 2	Ultrasonic bone knife, Bilateral 50%
Nie, 2013[36]	Disc T5:L1	TF	13 (7:6)	51 (40–69)	17 (6–41)	LA	50		77	54		28		11	CSF leak x 1	Hol-YAG laser
Ruetten, 2018[37]	Disc (47), stenosis (3), OFL (4), facet cyst (1) T1:T12	IL/TF/TR	55 (32:23)	56 (23–82)	18	GA				77	55		31	13	Epidural haematoma x 2; Dural tear x 2; Persistent myelopathy x 1, Revision x 1	
Ruetten, 2018[38]	Disc T6:T12	TF	26 (10:16)	58 (23–82)	6	GA	90 (40–155)	3.0 (2–6)		NS	73			11	Neuralgia x 2, Epidural haematoma x 1, Dural tear x 1	Sub-group of Ref 34
Shen, 2018[39]	Disc T5:T12	TF	16 (10:6)	55 (28–78)	21 (7–60)	LA	90 (55–180)			73					Revision to laminectomy x 1	
Xiaobing, 2019[40]	OLF/Disc/ OPLL T1:T12	TF	14 (7:7)	57 (33–78)		LA				81			57	9	Dural tear x 2	
Yang, 2019[41]	Thoracic TB	TF/TP	75	56 ± 12	36	GA	182 (130–250)		96 (Fusion)	85				10	Root irritation x 6; Graft absorption x 3	
Yu, 2020[42]	OPPL (T7-L1)	TF	15 (7:8)	56 (41–71)	20 (13–32)	LA	79 (43–132)	4.1 ± 1.1	71	64		79	40	10	Nil	
Cohort study																
Zeng, 2020[43]	Disc	TF	8 (6:2)	42 (26–57)	3	LA	78 ± 11								Muscle weakness x 1	Comparative randomly allocated cohorts: Endoscopy vs. laminectomy. Information and data incomplete Results of 8 in Table.

Note. TF, transforaminal; IL, interlaminar; TP, transpedicular; TR, transthoracic retropleural; LA, local anaesthetic plus sedation; GA, general anaesthetic; ODI, Oswestry Disability Index: improvement %; VAS, Visual Analogue Score: decrease %; OPPL, Ossification of Posterior Longitudinal Ligament; TB, Tuberculosis; OLF, Ossification of Ligamentum Flavum; JOA, Japanese Orthopaedic Association; RR, recovery rate = (postoperative JOA - preoperative JOA) / 11 or 18 or 29 - preoperative JOA) x 100%; MINORS, Methodological Index for Non-Randomized Studies: scored out of 16.

Table 3. Published case reports of full endoscopic treatment of thoracic disorder

Case reports	Pathology	Technique	*N* (m:f)	Age (range)	Follow-up months (range)	Anaesthesia	Op time mins (range)	VAS Back (Dec. %)	ODI (Inc. %)	JOA score (RR %)	Comments
Hur, 2019[44]	Disc T10/11	IL	1 (1:0)	65	1.5	GA	95				
Jia, 2018[45]	Discs T2/3, T10/11	TF	1 (1:0)	88	12	LA				67	
Joo, 2012[46]	Tumour T11	TF	1 (1:0)	82	1.5	GA					With percutaneous vertebroplasty
Kolcun, 2019[47]	Discitis T4/T5	TP	1 (0:1)	83	12.0	GA					Robotic navigation
Kong, 2018[48]	OPPL T1/2	TC	1 (0:1)	67	6.0	GA	225	74		64	Anterior cervical approach
Liu L, 2020[49]	OLF/Disc T10/11	IL	1 (0:1)	58	6.0	GA	110	100		84	
Liu W, 2019[50]	Disc T11/12	TF	1 (1:0)	28	6.0	LA	150	100	87		
Liu Y, 2017[51]	Disc T11/12	TF	1 (0:1)	56	1.0	LA	90	87	94		
Miao, 2018[52]	OLF T3/4, T9/10	IL	2 (0:2)	63,64		LA					
Middleton, 2017[53]	Stenosis T6:T11	TF	1 (0:1)	75	3.0	GA		89			Multi-regional stenosis
Quillo-Olvera, 2020[54]	Discs T7/8, T8/9, T11/12	TF	3 (2:1)	42 (41–43)	21 (1–60)	GA	123 (100–160)	87		88	Hybrid (tubular + TF)
Telfeian, 2015[55]	Ewings T5/T6	TF/TP	1 (0:1)	16	Nil	LA + sedation	77				Postop Chemotherapy
Wu, 2017[56]	Disc T7/8, T8/9	TF	1 (0:1)	41				100			

Note. TF, transforaminal; IL, interlaminar; TC, transcorporeal; TP, transpedicular; TR, transthoracic retropleural; LA, local anaesthetic plus sedation; GA, general anaesthetic; ODI, Oswestry Disability Index: improvement %; VAS, Visual Analogue Score: decrease %; OPPL, Ossification of Posterior Longitudinal Ligament ; TB, Tuberculosis; OLF, Ossification of Ligamentum Flavum; JOA, Japanese Orthopaedic Association score; RR, recovery rate = (postoperative JOA - preoperative JOA) / 11 or 18 - preoperative JOA) x 100%.

patient series with numbers included totalling 511, ranging from 6 to 92 (Table 2). One report[43] randomized eight patients to transforaminal endoscopy and eight to open posterior laminectomy using a random number table method. No information was provided regarding allocation concealment and data were incomplete. The trial is therefore referenced here as a cohort study rather than a randomized controlled trial. Thirteen articles were case reports with technical descriptions and limited outcome data (Table 3).

Technical aspects

Twenty articles used full endoscopy via a transforaminal approach and six via an interlaminar approach. The remainder were mixed, extraforaminal, transpedicular or transcorporeal. The technical aspects of surgery were similar in all papers with use of comparable instrumentation systems. Three surgical teams used a laser to aid decompression[30,33,36] and one an ultrasonic bone knife.[35] Kolcun et al,[47] described using robotic technology to aid instrument placement at the correct thoracic level. Operative time ranging from 48 to 250 minutes was heavily dependent on the number of levels involved and the pathology present.

Functional outcomes

All the patient series reported one or more functional outcome measures (Table 2). Of these, eight reported scores on one of the Japanese Orthopaedic Association (JOA) scoring systems allowing calculation of a recovery rate. This led to four surgical results falling into Excellent/Good category (scores > 50%) and four into a Fair category (25–49%).[28] All four case reports (less robust evidence) with JOA recovery rates suggested Excellent/Good results. Where reported there was a reasonable improvement in Visual Analogue Score (VAS) for back (78 ± 14%) and leg (75 ± 19%) pain post surgery. Mean Oswestry Disability Index (ODI) improved from 60 ± 7% to 19 ± 11% at final outcome ($p < 0.001$, paired *t*-test).

Complications

Complications are listed in Tables 2 and 3. Dural tears were reported in 11 of the 460 patients (2%), transient paraesthesia or neuralgia in 10 (2%), revision surgery in seven (1.5%), neurological injury in three (0.6%) and epidural haematoma in three (0.6%).

Review limitations

Although a search protocol was established framed in terms of patients undergoing surgery for thoracic pathology (P), receiving full endoscopic surgical intervention (I), with comparisons to open surgery where available (C), and detailing patient-reported outcome measures and complications (O),[57,58] individual search strategies were not formed for each identified source to take account of differences in indexing. The search was also primarily, although not exclusively, of original studies and any 'meta' literature, rather than extending this to secondary sources including unpublished/grey literature.[26]

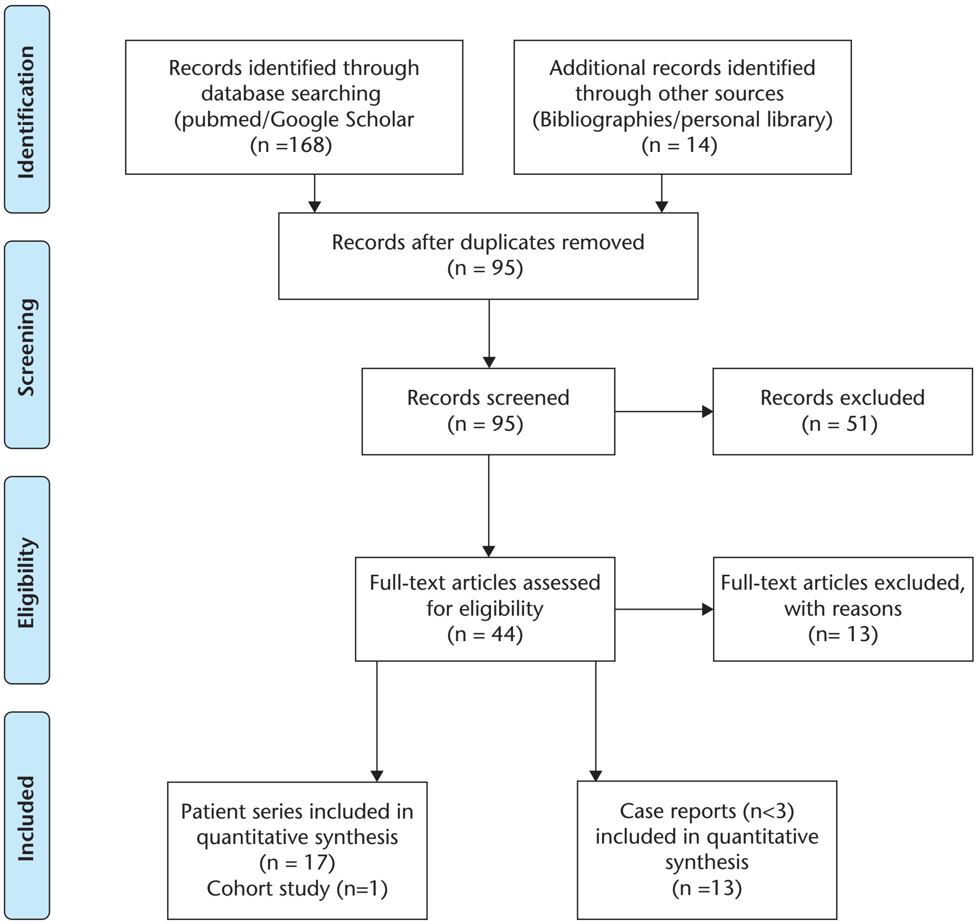

Fig. 7 PRISMA flow diagram outlining article selection.

The current literature remains limited to Level IV evidence.[59] Only one study had results with comparison to an open procedure and provided no comparison with continuance of conservative therapies. Where specified, similar endoscopic instrumentation systems were used (Clarus US, joimax GmbH, RIWOspine GmbH, Spinendos GmbH) and it was assumed that any differences in system were not a factor materially influencing the reported outcomes.

Discussion

It is clear from the results of this review that the future lies with the perfection of endoscopic surgical techniques applicable to the treatment of thoracic pathology. In the last five years there has been a significant increase in the literature pertaining to endoscopic procedures. Although primarily evidence is derived from patient series with Level IV evidence,[59] there is a reasonable uniformity in reported outcomes with assessments falling into the Excellent or Good category.

Considering thoracic discectomy, 14 reports were available with success rates equalling those reported elsewhere for grouped posterolateral approaches. Perhaps of greater significance is the clear evidence for a lower complication rate and shorter hospital stay. Complications common with open surgery,[7] including vertebral column instability, cerebrospinal fluid leak/pleural fistula, thoracic viscera injury, and intercostal neuralgia were not reported in any of the papers. Interestingly, neither was wrong-level surgery, presumably due to the necessity for multiple image intensifier radiographs during the procedure. In the future, it is likely that radiation dosage during endoscopy will be reduced by new innovations in image guidance, whether using localizing cameras, ultrasonic, electromagnetic or robotic technology, designed specifically for spinal application.

Based on the natural history of disc prolapse with a gradual resolution of symptoms with time by fragment resorption, it is generally recognized that resection of only the protruding fragment of a disc prolapse is required if surgery is essential.[60] This approach lends itself to minimally invasive techniques and obviates the necessity for spinal fusion after complete discectomy. This probably even applies to some of the situations where fusion has been felt essential in the past, such as cases of multilevel herniation, herniation in association with Scheuermann's disease and herniation at the thoracolumbar junction. The largest series in this review,[30] provides supportive evidence for this at the thoracic levels with a < 2% reported recurrence of prolapse at two years. The transforaminal approach has a distinct advantage over an interlaminar approach in that instruments do not need to be inserted between the thecal sac and the herniation, as the protruding disc is pulled out posterolateral to the cord. In an interlaminar approach the cannula and any curettes inserted occlude direct vision of the thecal sac unless rotated, resulting in a higher potential for cerebrospinal fluid (CSF) leakage from dural injury. Interlaminar surgery was mainly limited to patients with stenosis and ossification of the ligamentum flavum replicating the results from open surgery.[24,61] Calcification of the disc may also present unique problems and require the availability of specialist endoscopic instruments.[49]

Recent studies have focussed on the potential use of full endoscopy for the treatment of spinal stenosis in the thoracic region. In their paper, Xiaobing et al[40] included patients with ossification of the ligamentum flavum and/or posterior longitudinal ligament. In contrast to results from open techniques, that almost always require associated anterior or posterior spinal fusion,[62] they found no postoperative neurologic deterioration. It has been stated that endoscopy is inappropriate for the treatment of giant thoracic disc herniation, described as occupying greater than 40% of the thoracic canal diameter,[63] as an intradural extension has been reported in 15–70%.[1] Although use of a mini-thoracotomy or a retropleural approach have both been recommended,[64] modern advancements in imaging, coupled with laser resection, may now allow surgeons to consider full endoscopy for even these difficult pathologies.

During any spinal surgery preservation of the blood supply to the cord is paramount. To mitigate against damage, Court et al[1] suggested that at least in transthoracic approaches, arteriography to locate the Artery of Adamkiewicz should be considered as this could determine the optimal side for surgical exposure. Arterial damage is less likely with full endoscopy, since the approaches will be posterior or posterolateral, hence arteriography is not generally performed, avoiding its associated complications. There was no suggestion from our literature review that vascular impairment was a cause of ongoing myelopathy.

Uses of endoscopy for advanced spinal disease from infection and tumour have been reported in several publications.[65,66] One study (not included in Table 2 as treatments were primarily to the lumbar spine) described use of endoscopy to treat infective spondylodiscitis. After cannula insertion and abscess drainage the authors used endoscopy to enhance vision with minimal invasion for debridement and sequestrectomy.[65] Yang et al, in a relatively large series of patients with tuberculosis, describe coupling of percutaneous decompression of the spine with allografting and percutaneous pedicle screw fixation.[41] They reported excellent outcomes with 96% achieving acceptable fusion, although it was noted that their results were only from patients with single-level disease and small abscesses. The advantages of a water-mediated procedure with flushing of the targeted area were emphasized. Telfeian et al[55] describe the potential for use of endoscopy in tumour resection.

Complications from open surgery have been considered by several authors.[13,67] Lubelski et al[13] found that the mean complication rate for thoracotomy was 39% (n = 453), for the lateral extracavitary approach 17% (n = 157) and for costotransversectomy 15% (n = 164), but noted that 25% of patients receiving a thoracotomy were undergoing a palliative decompression and stabilization for spinal metastases. Brotis et al[67] reviewed different approaches for treatment of only thoracic disc herniation. Their meta-analysis included 15 primarily retrospective cohort studies of 1036 patients. Medical and surgical-site complications were the most common source of morbidity at 21% and 11%, respectively. CSF related and neurological complications were estimated to be 8% and 5%. In contrast, results from this review for endoscopy, although on smaller reported numbers, show significantly lower total complications at 8%. Heat injury from use of laser or radiofrequency might be a concern for the surgeon due to the anatomy of the thoracic canal, with a higher density of the spinal cord compared to the multiple roots in the lumbar region.[68] Although there is less CSF to buffer against heat, full endoscopy is performed under continuous irrigation mitigating this risk. It is interesting to note that, with respect to the open approaches, the lateral and posterolateral approaches had lower overall complications than the anterior approaches (although the latter were reduced with thoracoscopy), but were more liable to inadequate decompression. Whether there are any long-term consequences of smaller yet better-visualized areas of decompression with full endoscopic techniques will only show up in studies with longer follow-up. The likelihood is that the impact of further advancements in imaging with 4HD, 3-D and robotic technology[69] will improve surgical outcomes and reduce complications further.

Making an accurate interpretation of the current status of endoscopic surgery is to an extent limited by the small size of almost all the studies. However, the comparative open surgical cohorts are not actually much larger, a reflection of the relative rarity of most thoracic pathologies and hence a limitation of the number of cases presenting to a single unit. Probably for this reason randomized controlled trials producing Level I evidence are not available. The centralization of spinal surgery to regional centres in the UK and elsewhere should allow the production of better-quality evidence in the future.

Conclusion

Current literature demonstrates an international adoption of full endoscopic techniques for the treatment of thoracic spine pathology. The majority of reports describe a transforaminal approach for disc prolapse with interlaminar access used for the treatment of significant canal stenosis. Overall, there is now a moderate expectation of Excellent/Good postoperative outcomes with fewer complications than after open surgery. The increasing number of publications in the last three years suggests that full endoscopy is the technique of choice in many centres and will become the universal standard of patient care.

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ICMJE CONFLICT OF INTEREST STATEMENT
RDSG declares no conflict of interest relevant to this work.
RW reports consultancy for joimax GmbH and a webinar series for joimax GmbH outside the submitted work.
JNAG reports consultancy for joimax GmbH, a patent for an endoscopic retractor for joimax GmbH and a webinar series for joimax GmbH, all outside the submitted work.

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