Diaphragmatic mobilization technique for anterolateral thoracolumbar exposure

Mohamed Abdelaziz, Mahmoud Abdelghafar, Moheib S. Ahmed

Department of Orthopaedics, Mansoura University, Mansoura, Egypt

Correspondence to Mohamed Abdelaziz, Department of Orthopaedic, Mansoura University, Mansoura, Egypt, Tel: 00201001261525; e-mail: mortho2@yahoo.com

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Background
Traditional diaphragmatic incision to expose the thoracolumbar junction is associated with significant morbidity. In an effort to eliminate the drawbacks during and after thoracolumbar exposure, the technique of diaphragmatic mobilization has been developed to expose T12, L1 and upper L2 vertebral bodies.
Objective
The objective of this study was to demonstrate the feasibility and clinical experience of diaphragmatic mobilization technique to the thoracolumbar junction.
Materials and methods
Seventeen patients with spinal pathology at the thoracolumbar junction (T12, L1 and L2) underwent surgery using left-sided thoracotomy with diaphragmatic mobilization. In each case, the lateral aspect of the involved vertebra with the disc space proximal and distal was exposed with the mid-vertebra proximal and distal. Preoperative and intraoperative fluoroscopy was used to assure correct level together with daily postoperative chest radiography until chest drain removal. Operative results, complications and early outcomes were assessed.
Conclusion
Diaphragmatic mobilization allowed adequate thoracolumbar exposure to perform corpectomy, decompression and strut grafting plus or minus fixation without the need for circumferential release, thus avoiding its possible complications. In addition, it can be considered as an alternative for surgeons lacking experience, or facilities with video-assisted thoracoscopic surgery.

Keywords:
spinal fractures, spinal fusion, thoracolumbar junction

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Introduction

For certain types of fractures, tumours and infection of the spine associated with extensive destruction or defects of the vertebral body, and the intervertebral discs, anterior spinal reconstruction of the load bearing is required to avoid late correction loss and construct failure [1].

The thoracolumbar junction poses an anatomic dilemma given the presence of the lower rib cage and the diaphragm. The anterior thoracic spine can be exposed through a variety of techniques. Variable methods to access this area have been described, from a conventional open approach to a more minimally invasive approach [2]. The technique used is often determined by the affected spinal level, pathological process and surgeon preference. Posterior-based approaches include transpedicular, posterolateral costotransversectomy and lateral extracavitary. Anterior-based approaches include anterolateral and laparoscopic thoracotomy, lateral transthoracic and lateral retropleural thoracotomy [2].

We describe our early experience in which the thoracolumbar junction is exposed through left lateral thoracotomy, and the diaphragm is mobilized out of its vertebral attachment only allowing exposure down to L2 mid-vertebral level without incising the diaphragm, and thus minimizing the resulting morbidity.

Materials and methods

Demographic features

Over an average of 21 months (range between 6 and 39 ms), 17 consecutive patients underwent anterolateral thoracolumbar (T12, L1, proximal L2) exposure using the technique of diaphragmatic mobilization. They presented with the following: 14 cases with significant thoracolumbar spinal trauma and one case

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of late post-traumatic kyphosis, tuberculous spondylitis and osteoporotic spinal fracture, respectively.

Clinical and radiographic evaluation

All patients were evaluated according to the neurological performance scale by Frankel *et al.* [3] to compare the preoperative neurological status with the postoperative neurological status. The preoperative and postoperative Cobb angles were measured in the lateral radiograph of the thoracolumbar spine. To determine the Cobb angle [4] measurements were taken from the superior endplate of the vertebra one level above the affected vertebra to the inferior endplate of the vertebra one level below. In patients with burst fractures with significant canal compromise, after initial posterior transpedicular fixation, posterolateral decompression, Postoperative computed tomography to assess residual canal compromise and accordingly anterior decompression are performed. In those cases (post traumatic and infection) there is loss of anterior vertebral height soit is better be restored via anterior exposure. After anterior surgery, all patients were subjected to daily chest radiography until chest tube removal, with an additional postremoval radiography to confirm complete lung expansion, with no residual collapse.

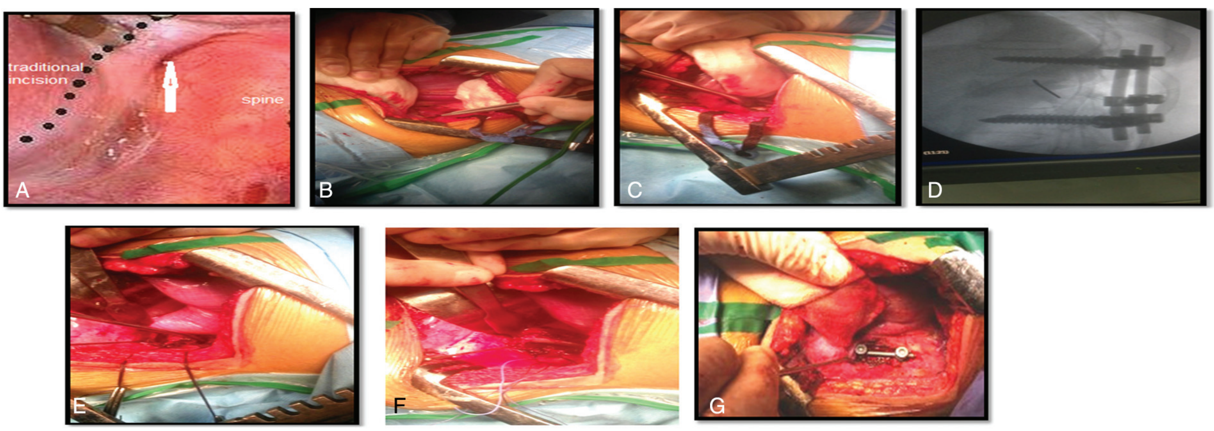
Surgical technique

The patient is positioned on his or her side and stabilized in this position with a suitable support at the level of the shoulder, and pelvis. In all patients, the thoracolumbar junction was approached from the left side. As a first step, the affected section of the spine is drawn onto the skin of the lateral abdominal and thoracic wall under image intensifier control. Careful attention should be given to correct the projection of the vertebrae, whose endplates, anterior margins and posterior margins should be displayed in the central beam, in sharp focus with no double contour.

T12, L1 and upper L2 were approached through the 10th rib bed. The rib was dissected subperiosteally from the underlying pleura and neurovascular bundle, and it was removed. The portion of resected rib was set aside for later use as an autograft. Once the chest cavity has been opened, the lung is retracted initially with the left hand, and the chest cavity is explored for pleural adhesion and other associated pathologies.

A large abdominal gauze is used for packing the lung, and the left lung is kept retracted with the aid of a lung retractor. The confluent area between the lateral aspect of the vertebral body, the aorta and the diaphragm is identified (Fig. 1a). Using long Kocher forceps with gauze sponge, held with left hand, a downward and distal retraction producing stretch over the diaphragmatic vertebral attachment, and just about 0.5 cm lateral to the aorta we start release using bipolar diathermy inducing a bloodless technique for diaphragmatic mobilization and releasing the diaphragmatic attachment (Fig. 1b) proceeding form medial to lateral till reaching the attachment of the medial arcuate ligament with L1 transverse process revealing the T12, L1 vertebral level. By maintaining continuous retraction, there will be progressive diaphragmatic detachment. Thereafter, the psoas muscle fibre attachment to T12, L1 annulus and L1 vertebral body starts to be revealed (Fig. 1c). Then, a double-angled spinal needle is inserted in the exposed

Figure 1



(a) Topographic view showing traditional diaphragmatic incision (dotted line) with arrow tip showing diaphragmatic vertebral attachment. (b) Intraoperative photo showing the diaphragm detached with ongoing psoas release. (c) Intraoperative photo with the diaphragm, and psoas released. (d) Intraoperative radiograph levelling. (e) Intraoperative photo with intervertebral proximal and distal discectomy. (f) Corpectomy with intervertebral rib grafting. (g) Intraoperative photo with screw-rod fixation.

disc to confirm correct levelling using image intensifier (Fig. 1d). The long Kocher forceps is then replaced with a large Cobb elevator resting on the lateral aspect of L1 vertebral body aiding downward and distal psoas fibre retraction during its release. The segmental vessels are identified crossing the vertebral waste, ligated with double silk sutures or cauterized along their course over the lateral vertebral body and cut in between. Dissection is then preceded sequentially, distally exposing L1, L2 annulus, releasing the psoas fibre attachment as far distally as possible reaching the L2 mid-vertebral body, anteriorly reaching the near-anterolateral vertebral border, and as far posteriorly as the base of the ipsilateral pedicles. This retraction is maintained with one Kirschner wire inserted in the posteroinferior part of the L2 vetebral body, a pointed Homman retractor inserted in the anteroinferior part of L2 vertebral body and stay sutures retracting the mobilized psoas fibres posteriorly. Two more pointed Kirschner wires as landmarks are inserted in the mid-vertebral endplates of adjacent levels of decompression and confirmed radiologically with image intensifier to mark the mid-sagittal points for proper graft and pyramish cage later positioning, and these points were marked for later identification before graft or mesh insertion. After complete exposure, partial lateral corpectomy (pedicle to pedicle) and spinal canal decompression is performed in cases of burst fractures with residual canal compromise, or debridement in cases of infection. A pyramish cage of proper size with part of the excised rib and bone chips from the corpectomy site impacted through the cage, and inserted in the corpectomy site as far anteriorly as possible between vertebral endplates, and further augmented laterally with Euros screw-rod fixation system in cases with thoracolumbar burst fractures. The selected proper cage size equaling to the defect, filled with autogenous bone graft is inserted in proper position under image intensifier (Fig. 1e–g). The defect created by diaphragmatic mobilization, which is about 4–5 cm, is obliterated spontaneously once diaphragmatic retraction is released, and the diaphragm recures to its original position without suturing. An intercostal tube connected to an underwater seal is inserted through the seventh intercostal space. Just before closure, the lung is inflated, while saline is poured in the pleural cavity, and the lung is inspected for any air leak. The wound is then closed in the usual manner. The patients were shifted postoperatively to the ICU, fast track, until establishment of their general condition, with full lung expansion. After chest tube removal, the patients were mobilized out of bed wearing moulded plastic body jacket, either weight bearing or with wheelchair, as tolerated with the aid of a therapist.

Results

The study included 17 patients. Their mean age was 34.5 years (range from 19 to 57 years) and the male-to-female ratio was 8: 2%, respectively. Mean follow-up period was 21 ms (range between 6 and 39 ms). The patient characteristics are summarized in Table 1. All patients underwent posterior transpedicular fixation. Fourteen of them who presented with neurologic injuries secondary to spinal canal compromise underwent posterolateral decompression followed by second-stage left-sided thoracotomy, diaphragmatic release and decompression through lateral partial corpectomy (pedicle to pedicle) with residual canal compromise more than 35% of original spinal canal dimension. There was one case with T12, L1 spondylitis, debridement, canal decompression, strut rib graft and biopsy, which revealed tuberculosis; one case with late post-traumatic kyphosis, on whom T12–L1 discectomy, release and strut rib graft fusion was performed; and one case with an initial diagnosis as T12 destruction for whom anterior decompression intervertebral fusion using pyramish and rib graft was performed, but by biopsy it was proven to be osteoporotic spinal fracture. Postoperative patients were followed up daily for intercostal chest tube output that was extracted when output was less than 100 ml/day on average of 5.5 days with a range between 4 and 7 days postoperatively.

Our patients were mobilized out of bed immediately on the second day of chest tube removal when they proved to be stable clinically with no postremoval clinical problems, except for one patient who developed pneumothorax after chest tube removal that necessitated tube reinsertion for 1 week until complete resolution.

The patient was mobilized wearing moulded plastic body orthosis, either with wheelchair or weight bearing with the aid of zimmer, as tolerated under care of the physiotherapist.

We had two patients diagnosed initially with pathological fracture, which, after intraoperative biopsy, was proven to be tuberculosis spondylitis for the first patient (T12–L1) and osteoporosis for the second patient (T12). There were no reported cases with intraoperative vascular, parynchymal lung injuries, cerebrospinal fluid leak, nor postoperative chylthorax or deep infection.

Table 1 The characteristics of patients

Number	Age/sex	Dennis/level	AO/level	Anterior decompression+	Initial Cobb	Post operative Cobb	Chest tube (days)	Initial Frankel	Follow-up Frankel	Follow-up (ms)	Compliations
1	47/male	Destructive lesion (TB) T12–L1	–	Decompression, biopsy+rib graft	11	6	4	d	e	16	–
2	27/female	Burst#T12	B2 (L1)	Decompression, Rib graft, pyramish and fixation	22	1	5	A	A	18	DVT
3	38/male	Burst#L1	A3 (L1)	Decompression, rib graft, pyramish and fixation	2°	7	5	C	D	24	_
4	29/male	Burst#L1	B1 (L1)	Decompression, rib graft, pyramish and fixation	16	0	6	C	D	22	_
5	24/male	Burst#L1	A3 (L1)	Decompression, rib graft, pyramish and fixation	20	12	5	B	C	23	_
6	30/male	Burst#L1	B2 (L1)	Decompression, rib graft, pyramish and fixation	34	1	6	C	E	39	_
7	57/male	Osteoporotic Burst#T12	A3 (T12)	Decompression, rib graft, pyramish and fixation	10	0	7	C	D	30	_
8	60/female	Burst#T12, compression#L1	A3 (–)	Decompression, rib graft, pyramish cage +fixation	18	6	6	B	8	20	_
9	17/male	Burst#L1	(L1)	Decompression, rib graft, pyramish cage +fixation	30	20	7	B	C	26	B_ed sore
10	34/female	Post-traumatic (old burst#T12, with T11, T12 kyphosis)	T12	T12-T11 disc, rib graft	36	20	5	C	E	30	–
11	25/male	Burst#L1	A3 (L1)	Decompression, rib graft+fixation	20	8	5	b	c	24	–
12	27/male	Burst#L1	(L1)	Decompression, rib graft, pyramish cage +fixation	23	3	4	b	c	24	–
13	37/male	Burst#T12	A3 (T12)	Decompression, rib graft, pyramish cage +fixation	32	10	6	b	c	6	_
14	40/male	Burst fracture L1	A3 (L1)	Decompression, rib graft, pyramish cage fusion	5	8 months	5	c	c	15	_
15	29/male	Burst B#T11	A3 (L1)	Decompression, rib graft, pyramish cage +fixation	11	2	5	c	d	6	Superficial wound infection
16	19/male	Burst#T12	(T12)	Decompression, rib graft	24	10	7	C	C	10	Pneumothorax
17	47/female	Burst#T12	(A3) T12	Decompression, rib graft, pyramish cage +fixation	20	8	5	C	D	25	–

AO, classification; DVT, deep vein thrombosis; TB, tuberculosis. The grades increased from A to E means improvement.

We had one case with postoperative grade 3 sacral sore that necessitated debridement and grafting with the aid of a plastic surgical team. We had another case with superficial wound infection at the thoracotomy incision that was treated with specific intravenous antibiotic course.

A total of 17 patients were classified into five groups according to the Frankel neurological performance scale: none of the patients were classified as grade E, in which there are no motor or sensory deficits; one patient (6%) was classified as grade D with preservation of useful function distal to injury; nine patients (53%) were classified as grade C with nonuseful motor function distal injury; six patients (35%) were classified as grade B with complete motor paralysis but with some residual sensation injury; and one patient (6%) was classified as grade A with no sensory or motor function preserved distal to the level of injury. Postoperatively, 16 patients (94%) showed neurological recovery, except for one patient (6%) who remained in grade A with no recovery. There were no reported cases with postoperative neurological deterioration. The mean preoperative Cobb (sagittal deformity) angle measured 20.7 (range 5°–36°), and the postoperative deformity angle significantly improved to a mean of 7.2 (range 0°–20°). There were no reported cases with posterior implant failure, anterior graft sinking, mesh or implant dislodgement. In addition, there were no reported cases with nonunion, as indicated by vertebral endplate, graft or mesh interface radiolucency.

Discussion

Surgical reconstruction techniques for disorders of the thoracolumbar spine have undergone a marked evolution over the past 18 years. Acute instability with structural damage to the anterior load-bearing spinal column and post-traumatic deformity represent the most frequent indications for surgery [5,6]. Surgical decompression of anteriorly located cord-compressive lesions and the durability of kyphosis correction in patients with significant ventral column destruction from a solely posterior approach have been unsatisfactory [7,8].

Given the anatomical conditions, considering the nature of the diaphragmatic attachment, the line of incision is important to prevent the occurrence of a postoperative diaphragmatic hernia. Of the two alternatives, radial incision of the diaphragmatic attachment in extension of the spinal axis or semicircular incision running parallel to the diaphragmatic attachment to the spine and the ribs, Beisse [1] in his study for endoscopic surgery on the thoracolumbar junction of the spine for 220 patients with T12, L1 burst fractures advised the semicircular incision for the following reason: because of the dome-like architecture of the diaphragm, an increase of intra-abdominal pressure from a semicircular incision parallel to the attachment causes the incised margins to come together and adhere spontaneously, whereas a radial incision in direct proximity to the orifices of the aorta and the oesophagus weakens the diaphragm fixation and causes the incised margins to gap. In our study, the diaphragm is not incised, but it is only mobilized out of its vertebral attachment, releasing the medial arcuate ligament only together with proximal psoas attachment as far posteriorly and laterally as the transverse process, giving adequate exposure of T12, L1 and L1, L2 discs down to L2 mid-vertebral body and allowing adequate L1 decompression, T12, L2 pyramish cage with graft only plus or minus fixation safely without difficulty. The mobilized part of the diaphragm is left without suturing, and it heals spontaneously to its original position over the lateral vertebral body. Kim *et al.* [9] performed video-assisted thoracoscopic surgery (VATS) for management of thoracic and thoracolumbar junction pathologies, including fractures, tuberculous spondylities, idiopathic scoliosis and tumours, allowing direct pathology visualization through small mini incisions. However, the most significant disadvantage of VATS is an extremely steep learning curve for proper thoracoscopic surgery, such as establishing proper orientation under the angled two-dimensional endoscopic image and performing the operation through small portals with long surgical instruments at longer distances from the target area. Another most common complication of VATS is intraoperative bleeding due to damage of the segmental and intercostal vessels [10].

In our study, the technique of diaphragmatic mobilization gives direct access to the vertebral pathology in difficult situation to be approached by VATS with adhesions as in case of osteomyelities of the spine, and spinal metastases with marked paraspinal pleural reactions, adhesive thickening of the parietal pleura and infilteration of the pleura by tumour or inflamed fibrous tissue [5], and also allowing direct canal decompression. Another advantage is that it allows harvesting an autologous rib graft through the same incision, which is usually not possible with VATS, abolishing remote donor site graft complication, direct and immediate dealing with intraoperative bleeding. Avoiding diaphragmatic incision minimizes intraoperative and postoperative complications, such as diaphragmatic denervation, secondary hernia, chylthorax and peritoneal injury with early, safe and sound postoperative mobilization.

Conclusion

Thoracolumbar exposure using the diaphragmatic mobilization technique without diaphragmatic incision allows good space with safe exposure for T12, L1 and L2 discectomies with intervening corpectomy, grafting and also fixation, thus minimizing comorbidities associated with circumferential diaphragmatic release.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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