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Thoracoscopic repair of thoracic spine trauma

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Summary. Modern concepts of treating thoracic and lumbar spinal trauma are based on posterior transpedicular fixation techniques which confer angular stability and instrument only a few levels of the spine. In addition, to prevent secondary losses in postoperative reduction of kyphotic deformities, transpedicular resection of torn discs, and inter- and intracorporeal bone grafting are included in the repair procedures for the entire damaged motion segment. However, due to the small size of the pedicles, a transpedicular approach to the injured vertebral body is not possible in the upper thoracic spine. Patients whose thoracic spine trauma is not serious enough to require ventral instrumentation through open thoracotomy, but who present with an unstable vertebral fracture, may profit from additional ventral bone grafting to stabilize the fracture. The present study examined the feasibility of thoracoscopic ventral bone grafting in seven patients with unstable fractures of the upper thoracic spine. For primary repair, we stabilized the fracture by using posterior transpedicular screw systems (rods or plates). Simultaneously, spongiosa was harvested from the posterior iliac crest and deepfrozen. Repair was completed a few days later via a ventral thoracoscopic approach. The main location of the ventral osseous defect was identified by intraoperative radiology. After mechanical removal of destroyed connective tissue and disc material, fusion was performed using the previously harvested spongiosa, which was placed into the intervertebral disc space and the anterior osseous defect. Our results show thoracoscopic bone grafting to be technically possible and associated with low morbidity, with a potential of yielding satisfactory long-term results.

Key words: Thoracic spine fracture – Thoracoscopy – Bone grafting

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Fractures of the upper and middle thoracic spine (T1-T10) are fairly common, comprising about 15% of all spinal fractures. Because the thoracic spine is extremely stiff and the spinal canal narrow, only injuries of considerable violence can produce fractures, frequently in association with spinal canal injuries. Flexion and compression are the major mechanisms for osseous injuries, since there is little rotary motion in the upper thoracic spine [5, 9].

Depending on the nature of the fracture and its accompanying neurologic symptoms, in addition to anterior instrumentation anterior decompression of the spinal canal and bone grafting may be indicated for sufficient repair of spinal and spinal canal lesions [12, 15]. Anterior access to the thoracic spine usually involves lateral thoracotomy, especially if fractures of the middle and lower one-third of the upper thoracic spine (T3-T10) are to be treated. However, lateral thoracotomy carries a significant incisional morbidity, inherent in any intrathoracic procedure. Besides immediate postoperative respiratory difficulties and incisional pain, lateral thoracotomy often results in chronic pain [17].

For several years, video-assisted thoracic surgical techniques have been used in certain complex therapeutic procedures, and thoracoscopic approaches have thus been explored as a potentially less invasive means to manage a wide variety of intrathoracic pathologic problems, including spinal disease. Video-assisted thoracoscopic discectomy, removal of protruded discs, biopsy of vertebral bodies, and vertebral fusion to correct scoliosis or kyphosis have all been reported recently [18, 22, 23]. The present paper explores the feasibility of video-assisted thoracoscopic discectomy and bone grafting to optimize treatment of selected fractures of the upper thoracic spine.

Materials and methods

Since May 1993, we have used video-assisted thoracoscopic discectomy and bone grafting in eight cases of thoracic spinal fracture. Initial instrumentation and stabilization of the fractured vertebrae were done from a posterior approach as soon as possible after admission of the patient. At the same time, autologous cancellous bone chips and spongiosa were harvested from the posterior iliac crest and deep-frozen. To plan the spinal stabilization in the ventral portion, lateral conventional tomograms or CT reconstructions were obtained postoperatively. It was possible, thereby, to analyze the spatial relationship between the dorsal implant and the ventral osseous defect in the realigned fractured vertebra. The main location of the defect (in the cranial or caudal portion of the vertebral body) was determined. Ventral thoracoscopic completion of the repair was performed in a second procedure a few days after the primary treatment. Informed, voluntary consent was obtained from all patients following detailed explanation of the experimental nature of the procedure and its inherent advantages and disadvantages.

Thoracoscopic treatment of spinal fractures used standard equipment and operative set-up as described previously [3, 19, 22]. All procedures, including use of a double-lumen tube for selective collapse of the right lung and continuous hemodynamic monitoring, were performed with the patient in the left lateral position and under general anesthesia. The patient was always prepared for full thoracotomy, if needed. After lung collapse and CO_2 insufflation to 8–10cm H_2O, a rigid 30°-angled scope with a single chip camera attached (Karl Storz, Tüttlingen, Germany) was inserted through a trocar (Ethicon, Hamburg, Germany). This trocar had been inserted previously in the midaxillary line and in an intercostal space which depended on the level of the thoracic spine to be accessed. An initial exploratory thoracoscopy was then performed. The damaged vertebra could be identified with ease in all cases by locating the characteristic subpleural hematoma covering it.

Following the initial exploratory thoracoscopy, a second trocar was placed ventrally to the scope to advance an endoscopic lung retractor (Ethicon, Hamburg, Germany) to allow lung retraction toward the mediastinum. Two additional trocars were then placed in a triangular fashion converging on the affected vertebra (Fig.1). Two working ports had to be available at the level of the vertebral body being approached. The optical system was placed two spaces below, to allow use of the 30° angle for visualizing the vertebral body. Instruments were at least 30cm long to reach the spine comfortably.

Once the thoracic spine, including the fractured vertebral body, was easily visible through the parietal pleura, a Kirschner wire was inserted through one long working trocar and placed on the vertebral body at the site of maximum bony defect, as indicated by postoperative tomography. The correct positioning of the wire was confirmed by intraoperative radiology. Subsequently, the working trocar was advanced and placed directly on the damaged portion of the vertebral body. After removal of the wire, the vertebral body and the damaged intervertebral disc were entered. Destroyed connective tissue and disc material were carefully removed by curettes, forceps, and rongeurs.

To complete the anterior procedure, fusion was performed, using bone chips and previously harvested spongiosa, which were placed into the intervertebral disc space and the anterior osseous defect of the vertebral body. Bone was grafted through the same trocar as was used to resect the damaged disc. The position of the trocar remained unchanged throughout the procedure. To compress and position the bone grafts, cancellous bone was gently pressed through the trocar into the desired sites in the vertebral body or intervertebral disc space. The bone graft was then inspected, and any bleeding controlled by bipolar electrocautery. Finally, a chest tube was placed adjacent to the operative site, and the lung was re-expanded.

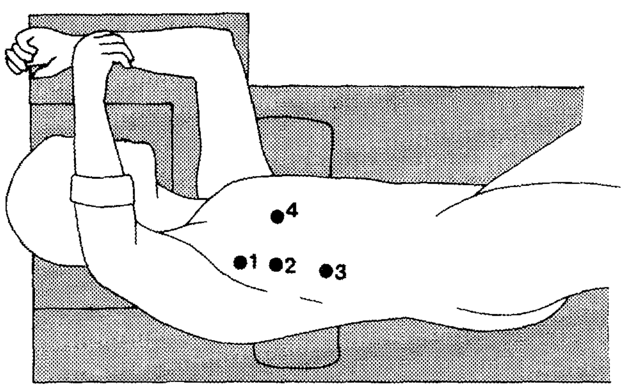


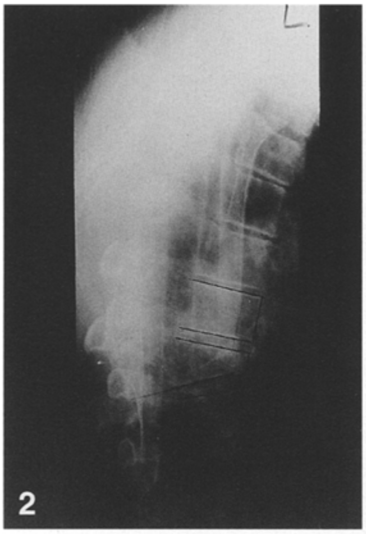
Fig. 1. Position of trocar sites on the right thorax. The working canals (*1–3*), including the channel for the optical system (*3*), converge on the spine. The channel for the endoscopic retractor (*4*) is situated ventrally

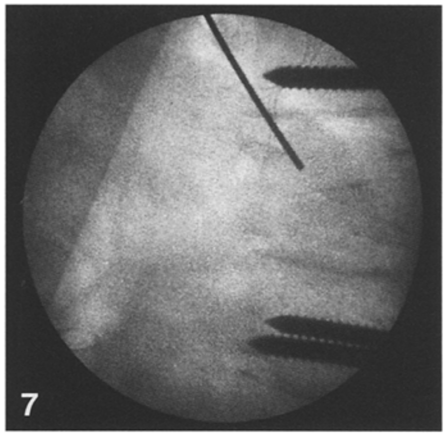
Results

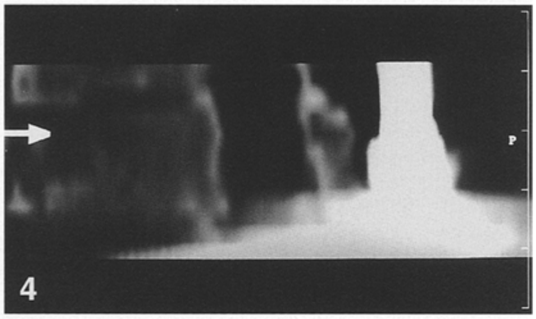
Figures 2–10 show our procedure of thoracoscopic spine repair in a representative patient. This patient had an unstable wedge compression fracture of T8 (Fig. 2) which was combined with dorsal disruption of all ligaments, and had resulted from a motorcycle accident. CT scans of this fracture demonstrated a ventral osseous defect (Fig. 3). Dorsal instrumentation, reduction of posttraumatic kyphosis, and stabilization were carried out from T7 to T9 by using an internal fixator [7]. Postoperative X-ray examination of the thoracic spine showed good initial reduction which, however, was associated with a ventral osseous defect identified by CT reconstruction (Fig. 4). Four days later, thoracoscopic bone grafting was performed at T8. At the initial exploratory thoracoscopy, the damaged vertebra could be identified without difficulty, since it was covered by the characteristic subpleural hematoma (Fig.5). A Kirschner wire was then placed on the vertebral body at the site of maximum bony defect as indicated by postoperative CT reconstruction (Fig.6). Intraoperative radiology confirmed the correct position of the wire (Fig.7). The working trocar was then placed directly on the damaged portion of the vertebral body. The wire was then removed and the vertebral body and the damaged intervertebral disc were entered using curettes and rongeurs to remove destroyed connective tissue and disc material (Fig.8). Subsequently, anterior bone grafting was performed as described above. Figure 9 shows the site of bone grafting after completion of the procedure. On final postoperative X-ray examination, the posttraumatic kyphosis had been reduced and the site of the previous anterior bony defect was filled with bony material (Fig.10).

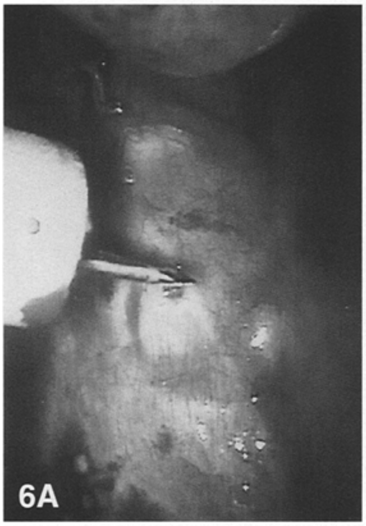
At follow-up, initial reduction was still evident 12 months after surgery. Correction loss from the immediate postoperative evaluation was 1.5°.

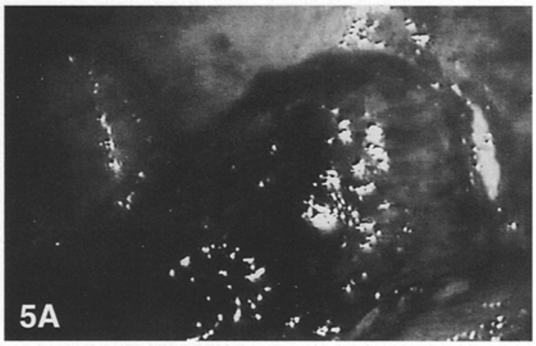
All patients who underwent thoracoscopic surgery had kyphotic fractures between T5 and T8. Six patients had vertebral burst fractures, which were unstable because the dorsal portion of the vertebral body was included in the fracture, as seen on CT scans. Two patients had stable wedge compression fractures which had resulted in a kyphotic angle of more than 25° and a ventral height loss of about one-third of the original vertebral height. No patient had neurologic symptoms or demonstrated any significant narrowing of the spinal canal (> ⅓) at the level of the injured vertebral body. For dorsal repair and correction, Dick's internal fixator [7] was used in two patients at T8. In five patients, the fracture was stabilized by Wolter's pressure plate fixator [27] at T5 and T6. In one patient, who had a burst fracture of T5 and a wedge compression fracture of T4, stabilization was carried out from T3 to T6 using Roy-Camille pedicle screw plates [24].

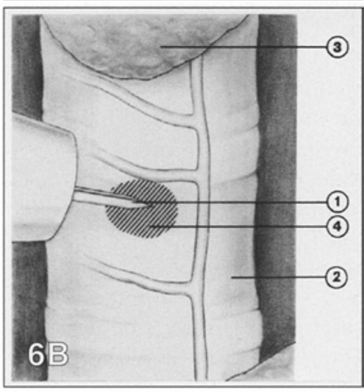












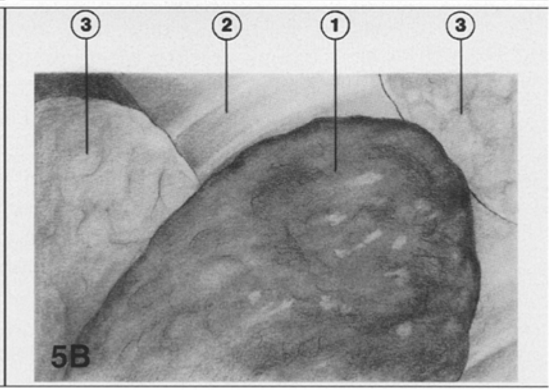


Fig. 2. Lateral view of the thoracic spine in a 28-year-old patient with an unstable wedge compression fracture of T8

Fig. 3. CT scan of T8 in the patient from Fig. 2, showing an unstable fracture with a ventral osseous defect (*arrow*)

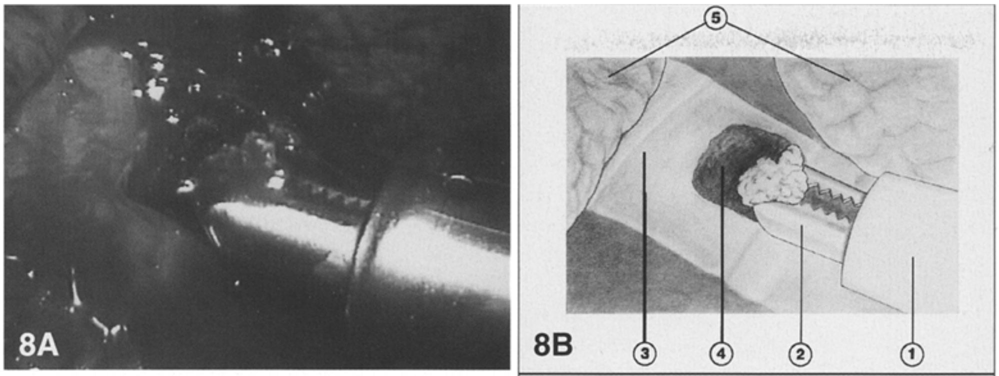
Fig. 4. CT reconstruction of T8 from Figs. 2, 3 after posterior repair of the thoracic spine fracture. Dorsal instrumentation, reduction of posttraumatic kyphosis and stabilization were done from T7 to T9 using an internal fixator. A good initial reduction was achieved which, however, was associated with a cranial, ventral osseous defect at T8 (*arrow*)

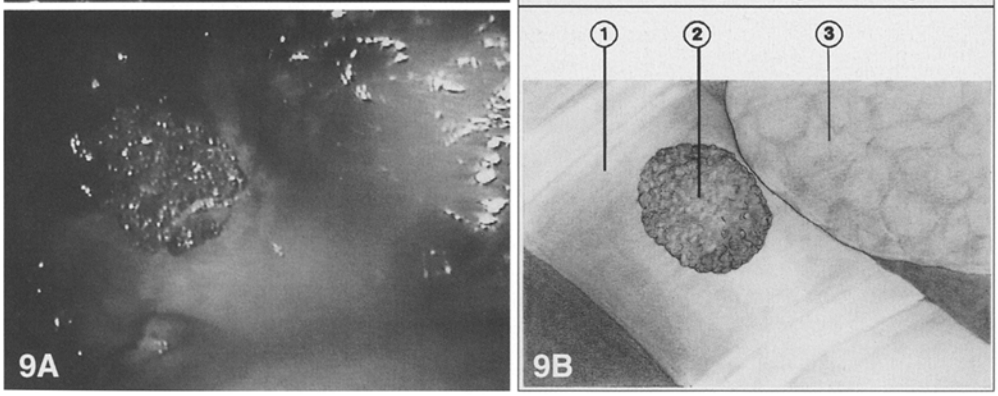
Fig. 5A, B. Anterior thoracoscopic repair of the thoracic spine fracture, stage I. To perform an initial thoracoscopy, a rigid 30°-angled scope with a single chip camera attached, was inserted through a trocar in the midaxillary line. **A** The camera revealed the characteristic subpleural hematoma which covered the damaged vertebra. **B** Explanatory scheme of the anatomical situation in Fig. 5A. *1*, Subpleural hematoma; *2*, vertebral bone; *3*, lung

All procedures were successfully completed by thoracoscopy, without postoperative morbidity or mortality. The neurologic status of all patients remained unchanged after surgery. Operating times averaged 60min. Compared to open procedures, thoracoscopic repair resulted in a shorter duration of narcotic usage. The mean follow-up period in the first six patients (8 months) was not long enough to allow definitive conclusions with respect to long-term losses in postoperative correction of kyphotic angle. However, so far, no patient has demonstrated a significant loss.

Fig. 6A, B. Anterior thoracoscopic repair of the thoracic spine fracture, stage II. **A** A Kirschner wire was inserted through one long working trocar and placed on the vertebral body at the presumed site of maximum bony defect, as indicated by postoperative CT reconstruction. The latter had been done previously, after completion of the posterior plating. **B** Explanatory scheme of the anatomical situation in Fig. 6A. *1*, Kirschner wire; *2*, fractured vertebral body; *3*, lung; *4*, presumed site of maximum ventral damage

Fig. 7. Anterior thoracoscopic repair of the thoracic spine fracture, stage III. The correct positioning of the wire was confirmed by intraoperative radiology





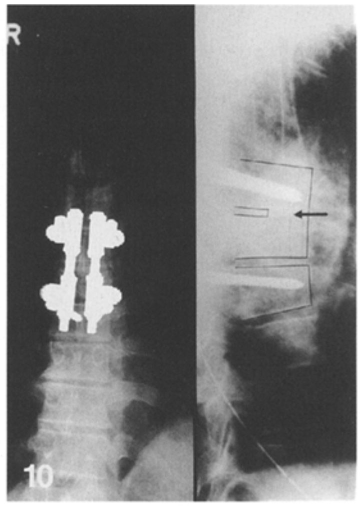


Fig. 8A, B. Anterior thoracoscopic repair of the thoracic spine fracture, stage IV. **A** The working trocar was advanced along the wire and placed directly on the damaged portion of the vertebral body. After retraction of the wire, the vertebral body and the damaged intervertebral disc were entered. Curettes, forceps, and rongeurs were used to remove destroyed connective tissue and disc material. **B** Explanatory scheme of the anatomical situation in Fig.8A. *1*, Working trocar; *2*, forceps; *3*, fractured vertebral body after dissection of the parietal pleura; *4*, site of maximal ventral damage; *5*, lung

Fig. 9A, B. Anterior thoracoscopic repair of the thoracic spine fracture, stage V. **A** Fusion was performed by using bone chips and previously harvested spongiosa, which were placed into the intervertebral disc space and the anterior osseous defect of the vertebral body. To compress and position the bone grafts, cancellous bone was gently pressed through the trocar into the desired sites in the vertebral body or intervertebral disc space. The figure shows the site of bone grafting after completion of the procedure. **B** Explanatory scheme of the anatomical situation in Fig.9A. *1*, damaged vertebral body; *2*, site of ventral bone grafting; *3*, lung

Fig. 10. Final postoperative bilateral X-ray examination of the thoracic spine. Posttraumatic kyphosis has been reduced by posterior fixation (internal fixator) and the ventral defect is now being filled with bony material (*arrow*)

Discussion

Flexion and compression are the major mechanisms for osseous injuries of the thoracic spine. Surgical treatment of thoracic spinal fractures depends on the type of fracture and associated neurologic deficit. In patients with unstable fractures, it is commonly accepted that surgery allows early mobilization, facilitates rehabilitation, and corrects kyphotic deformity [2, 10, 14]. Another indication for surgical intervention is the need for decompression in patients with incomplete neurologic deficit or with a significant, but asymptomatic narrowing of the spinal canal [2, 16, 27]. (In contrast, patients with complete neurologic deficit rarely have any neurologic recovery, regardless of the type of surgical procedure performed [5]). Furthermore, surgery significantly reduces long-term morbidity after spinal fractures in comparison to conservative treatment [13] and may also reduce hospital cost and time [16].

Various competing instrumentation systems are available to stabilize and correct the spine via the dorsal approach, which is usually the method of choice. Modern posterior fixation techniques are based on transpedicular screw systems and allow rigid segmental fixation along all three columns of the spine, although only a few levels of the spine are instrumented or fused [1, 6–8, 10, 11, 16, 21, 24]. However, in the lumbar and thoracolumbar spine, exclusive posterior repair may not always completely prevent certain long-term losses of immediate postoperative correction and kyphotic reduction [8, 10, 11]. The return towards preoperative kyphotic angles may occur because of collapse of the fractured vertebral body or narrowing of the disc space above the injured vertebral body [6, 21, 25]. Therefore, transpedicular disc resection, vertebral body reduction, and inter- and intracorporeal bone grafting through a posterior approach have been added to the posterior repair procedures. These procedures are extremely effective in preventing long-term loss of postoperative correction and kyphotic reduction [1, 6, 21, 26]. Consequently, repair of unstable spine fractures should combine posterior tension plating and anterior buttressing (Fig.11).

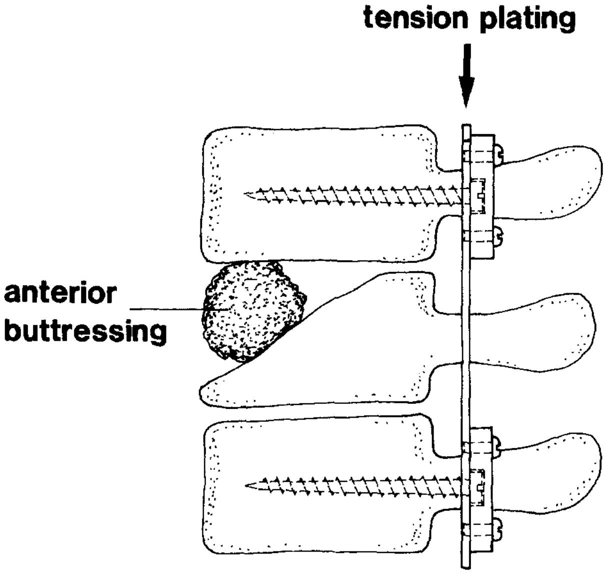


Fig. 11. Therapeutic approach to thoracic wedge compression injuries. Posterior repair is carried out using transpedicular screw systems (rods or plates) which confer angular stablility. For ventral repair, cancellous bone deficiencies in the vertebral body are replaced by bone grafting, the torn disc is removed, and the intervertebral space is filled with cancellous bone

Therapeutic approaches to thoracic spine fractures differ somewhat from those for lumbar or thoracolumbar spine fractures. Thus, posterior repair is restricted to the use of certain fixation systems. The physical dimensions of pedicle screw-rod systems (internal fixators) prevent their use cranially to T8 [7]. Therefore, pedicle screw-plate systems are the only means of stabilization at this location. A pressure plate fixator recently developed by Wolter [27] which uses smaller pedicle screws, seems a likely candidate, since its biomechanical characteristics resemble those of the internal fixator [11]. If more than one vertebral body is injured, instrumentation will require longer pedicle screw-plates with somewhat less favorable biomechanical qualities, such as those of Roy-Camille plates [24].

Furthermore, long-term loss of immediate postoperative correction and kyphotic reduction are, from a biomechanical point of view, usually less relevant in the thoracic spine than in the lumbar or thoracolumbar spine. In addition, the cranial pedicles progressively decrease in size above T10 [8], and adequate transpedicular disc resection and intra- and intercorporeal bone grafting are no longer possible above this level, since the pedicles at this site cannot be reamed to the required 6-mm width [6]. Until recently, only aggressive surgical techniques allowed ventral bone grafting at the level of the thoracic spine. These techniques were, therefore, restricted to patients with selected types of spinal fracture. Thus, patients with incomplete neurologic deficit, in whom laminectomy does not sufficiently decompress the narrowed spinal canal, or patients who present with large bony fragments in the spinal canal which resist ligamentotaxis, may require a lateral excavitary approach or open thoracotomy to produce adequate anterior or lateral decompression. In addition, excessive ventral destruction or dislocation of the spine may sometimes only be repaired by anterior instrumentation through a thoracotomy [12, 15]. In these cases, ventral bone grafting can be done simultaneously without special effort.

However, patients with unstable thoracic spine fractures, but without significant compression of the spinal canal, or with complete dissection of the spinal cord, would require – besides dorsal instrumentation – only ventral bone grafting to completely stabilize the lesion. Both open thoracotomy and use of a lateral excavitary approach – which involves rib and soft tissue dissection and removal, further destabilizing the fractured vertebra [4] – represent significant additional injuries in these patients. The harm done by these injuries has so far been considered to outweigh their clinical benefit with respect to long-term outcome. On the other hand, it is beyond doubt that a certain (albeit small) number of patients will suffer from chronic health problems because of persistent, secondary anatomic deformities at the thoracic spine due to a long-term loss of postoperative kyphotic correction. As a consequence, rehabilitation is prolonged, resulting eventually in reduced ability or long-term inability to work. If a thoracoscopic approach is used for ventral bone grafting in these patients, only minor surgical trauma will be added to the posterior procedure, thereby optimizing accepted therapeutic concepts.

Such a minimally invasive approach will result in significantly lower morbidity as demonstrated in a recent prospective study [20], in which, following thoracoscopic surgery, patients were found to have significantly less postoperative pain, as well as less impairment of pulmonary function and less shoulder girdle motion limitation than did those who had the equivalent procedure performed by thoracotomy.

Our study indicates that intra- and intercorporeal bone grafting can be achieved via video-assisted thoracoscopy – an approach which may yield satisfying long-term results with respect to eventual loss of postoperative reduction of kyphotic deformity. Although our study did not include a comparison group, it is our impression that thoracoscopic bone grafting confers the same clinical results with respect to fracture stabilization as does open thoracotomy. A similar conclusion was obtained from studies using thoracoscopy for disc space fusion in patients with kyphosis/scoliosis [22].

Whether thoracoscopy allows more complex vertebral repairs, such as calculated decompression, depends on the experience of the treating surgeon and on the future development and implementation of procedure-specific instrumentation. According to our experience, thoracoscopic dowel resection and application and spinal decompression also seem possible. At the moment, thoracoscopic treatment of thoracic spine trauma remains at the investigational stage.

Conclusion

In conclusion, we examined a two-stage procedure for repair of unstable fractures of the upper thoracic spine. For primary repair, we stabilized the fracture using posterior transpedicular screw systems (rods or plates). Simultaneously, spongiosa was harvested from the posterior iliac crest and deep-frozen. Repair was completed a few days later via a ventral thoracoscopic approach. The main location of the ventral osseous defect was identified by intraoperative radiology. After mechanical removal of destroyed connective tissue and disc material, fusion was performed using the previously harvested spongiosa, which was placed into the intervertebral disc space and the anterior osseous defect. Our results show thoracoscopic bone grafting to be technically possible and associated with low morbidity, with a potential of yielding satisfactory long-term results.

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