REVIEW ARTICLE

Anterior spine surgery in recent thoracolumbar fractures: An update

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KEYWORDS
Fracture; Thoracolumbar spine; Anterior approach

Summary  Surgical treatment of thoracolumbar spine fractures aims to achieve bony union and restore spinal anatomy. It may associate, as needed, decompression, reduction, graft and/or internal fixation, using a posterior, anterior or combined approach. Indications for an anterior approach weigh the pros and cons as well as the type of osteo-ligamentous lesion, degree of instability and patient’s neurological status. The main interest of an anterior approach is to enable medullary decompression by corporectomy while allowing reconstruction of the anterior spine. The technique was less frequently used mainly due to its associated morbidity risk; but the development of videoscopy tools now allows less invasive surgery, compared to conventional thoracophrenolombotomy. Given also the mechanical drawbacks of posterior assembly in certain types of fracture, a video-assisted anterior approach is becoming more common. A conjunction of a staged anterior followed by a posterior approach has progressively developed, to address the needs of spinal trauma: this encompasses posterior surgical reduction-internal fixation, sometimes performed in emergency, with or without laminectomy followed by corporectomy, then anterior spinal reconstruction by graft with or without osteosynthesis to improve medullary decompression and avoid secondary correction loss and non-union. Adapting vertebroplasty techniques to spinal traumatology should gradually limit indications for an anterior approach for purely mechanical purposes; this later will, however, logically remain indicated when anterior spinal cord compression is present with associated neurological deficit, whether or not persisting after posterior reduction-osteosynthesis.

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Introduction

Surgical management of thoracolumbar fracture has three objectives: to reduce the traumatic spine deformity, to restore spinal canal anatomy in case of medullary decompression, and to achieve consolidation by stabilizing the spine by osteosynthesis, sometimes associated to bone graft.
To these ends, the approach may be posterior, anterior or combined, in whichever order. Presence of neurologic disorder and anatomopathologic fracture type determine the role of surgery in most reports, but indications for an anterior approach remain poorly defined.

Surgical techniques

Surgical technique depends on the objective of the operation: osteosynthesis of an unstable lesion, medullary decompression by corporectomy, or reduction of traumatic displacement and/or graft for bone loss. Primary posterior osteosynthesis will determine the requirements of a subsequent anterior approach according to the resulting decompression and stability.

Surgery is classically performed under selective intubation to collapse the operated lung. Projection of the fractured vertebra onto the wall of the thorax under image intensification determines the level of the incision, which should be exactly perpendicular to the vertebral body, as the distance between wall and spine entails a long instrumental trajectory.

Patient installation

Installation in dorsal decubitus is recommended by certain classical authors [1,2], using conventional approaches and in order to avoid fixation in scoliosis, whereas lateral decubitus is recommended for video-assisted techniques [3,4].

Surgical approach

The approach is either minimally invasive, if video-assisted [4—7], or a classically left thoracophrenolombotomy for conventional procedures, as well described by Louis [8,9] (Fig. 1). The most frequent technique is mini-thoracotomy of about 5 cm, associated to two parietal introducers (one for the lens, introduced two or three spaces above in the axis of the spine, and one1 for the retractor and aspirator,

To restore vertebral body height, Kaneda uses a distraction hook pivoting on the screw heads [11,12], which entails a risk of asymmetric reduction. Louis and Goutallier, operating in dorsal decubitus, prefer traction, with an inflatable support cushion and angulating the table [8,13]. In lateral decubitus, reduction is mainly achieved by direct pressure on the spinous processes [4], which is an approximate, imprecise and non-reproducible technique. Madi et al. thus demonstrated the interest of a distraction hook symmetrically supported on the adjacent vertebral plates [4].
Anterior spine surgery in recent thoracolumbar fractures: An update

Figure 3  L2 burst fracture (Magerl type A3) with Frankel B paraplegia. Pre- and post-op CT, sagittal reconstruction. Reduction-laminectomy and osteosynthesis by initial posterior approach followed by partial posterosuperior corporectomy with anterior arthrodesis by tricortical graft and screwed plate. Incomplete neurologic recovery (Frankel D paraplegia).

Graft

In order to avoid secondary correction loss, the graft should be set between the two vertebral plates adjacent to the fractured body, rather than trying to fill the space in the body by impaction [14]. There may be an indication for isolated body graft following very stable posterior assembly. We prefer a tricortical iliac graft (Fig. 5), ideally positioned opposite the plate so as to improve assembly stability [10,15]. Certain authors use a vertebral body reconstruction cage, maintaining height and lordosis, filled with cancellous bone or bone substitute (Pyramesh™ cage, Medtronic Sofamor Danek) [4,7].

Instrumentation

Many types of synthesis material are used, some of which were developed specifically for endoscopy. Many are based on body anchors introduced beforehand, onto which rods or plates are fixed (Table 1) [10,16–18], with the advantage of positioning the screws before the hemorrhagic stage of corporectomy. Ideally, the two or three vertebral body screws should be bicortical, length 30 to 50 mm [4,10,15,17,19]. In case of close contact, interposition material can be used to separate plate and aorta [20].

Results

Results are given for 19 series, comprising 1054 cases of surgery on an anterior approach; all or almost all cases are of dorsolumbar hinge involvement (Table 2).

![Figure 4](https://example.com/figure4.png)  Peroperative view of anterior decompression by partial T11 corporectomy. The full width of the dural sheath should be visualized.

![Figure 5](https://example.com/figure5.png)  Peroperative view of conventional L1/L3 corporectomy/anterior arthrodensis. Impacting tricortical iliac graft.

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Table 2  Published series in anterior surgery for dorsolumbar fracture.

<table>
<thead>
<tr>
<th>Authors [ref.]</th>
<th>Series</th>
<th>Date</th>
<th>Material</th>
<th>Types of fracture</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunn [16]</td>
<td>48</td>
<td>1984</td>
<td>Dunn material</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Kaneda et al. [10]</td>
<td>150</td>
<td>1984</td>
<td>Kaneda plate</td>
<td>Burst fractures</td>
<td>8 yrs (5—12 yrs)</td>
</tr>
<tr>
<td>MacAfee et al. [3]</td>
<td>70</td>
<td>1985</td>
<td>Graft only (23 post</td>
<td>Burst, Chance, flexion-distraction and</td>
<td>3.4 yrs (2—8.6 yrs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>syntheses)</td>
<td>translation</td>
<td></td>
</tr>
<tr>
<td>Kostuik [18]</td>
<td>80</td>
<td>1988</td>
<td>Isolated decompression</td>
<td>Burst fractures</td>
<td>Not specified</td>
</tr>
<tr>
<td>Transfeldt et al. [26]</td>
<td>49</td>
<td>1990</td>
<td>(all after 3 mo)</td>
<td>Not specified</td>
<td>1–19 yrs</td>
</tr>
<tr>
<td>Dunn [16]</td>
<td>48</td>
<td>1984</td>
<td>Dunn material</td>
<td>Burst fractures</td>
<td>3.1 yrs</td>
</tr>
<tr>
<td>Kaneda et al. [10]</td>
<td>150</td>
<td>1984</td>
<td>Kaneda plate</td>
<td>All 3-column Magerl type B or C</td>
<td>31 mo (9—50 mo)</td>
</tr>
<tr>
<td>MacAfee et al. [3]</td>
<td>70</td>
<td>1985</td>
<td>Graft only (23 post</td>
<td>Burst fractures</td>
<td>3.4 yrs (2—8.6 yrs)</td>
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<td></td>
<td></td>
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<td>translation</td>
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<td>Isolated decompression</td>
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<td>(all after 3 mo)</td>
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<td>syntheses)</td>
<td>translation</td>
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<td>1988</td>
<td>Isolated decompression</td>
<td>Burst fractures</td>
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<td>Transfeldt et al. [26]</td>
<td>49</td>
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<td>MacAfee et al. [3]</td>
<td>70</td>
<td>1985</td>
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<td>Burst fractures</td>
<td>3.4 yrs (2—8.6 yrs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>syntheses)</td>
<td>translation</td>
<td></td>
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<tr>
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<td>1988</td>
<td>Isolated decompression</td>
<td>Burst fractures</td>
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<td>1990</td>
<td>(all after 3 mo)</td>
<td>Not specified</td>
<td>1–19 yrs</td>
</tr>
<tr>
<td>Dunn [16]</td>
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<td>1984</td>
<td>Dunn material</td>
<td>Burst fractures</td>
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</tr>
<tr>
<td>MacAfee et al. [3]</td>
<td>70</td>
<td>1985</td>
<td>Graft only (23 post</td>
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<td>3.4 yrs (2—8.6 yrs)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>syntheses)</td>
<td>translation</td>
<td></td>
</tr>
</tbody>
</table>

Complications

The risks inherent to an anterior approach to the thoracolumbar spine comprise prespinal arterial or venous wounds [5,14,16] or, exceptionally, thoracic canal wounds. Deep sepsis is a very rare complication. In the 12 reports that detail complications, only five deep infections occurred out of 549 cases: i.e., 0.95% [4,5,7,11,12,14,18,19,21–24], or 0.7% in Verlaan’s meta-analysis (for 607 anterior approaches, versus 2% in posterior surgery) [25].

Without primary posterior stabilization surgery, mean surgery time ranges from 2.5 to 5.5 h (Table 3) (4.5 h in Verlaan’s meta-analysis). Mean peroperative bleeding ranges from 0.6 to 2.5 liters (Table 3) (1.3 liters in Verlaan’s

Table 3  Surgery time and peroperative bleeding in anterior decompression-arthrodesis for dorsolumbar spinal fracture.

<table>
<thead>
<tr>
<th>Authors [ref.]</th>
<th>Surgery time</th>
<th>Per-op bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hass et al. [22]</td>
<td>5.5 h</td>
<td>2.250 ml (500—4,800)</td>
</tr>
<tr>
<td>Okuyama et al. [23]</td>
<td>5.5 h</td>
<td>2.300 ml</td>
</tr>
<tr>
<td>Carl et al. [64]</td>
<td>5 h</td>
<td>851 ml (121—2025)</td>
</tr>
<tr>
<td>Schultheiss et al. [7]</td>
<td>2.5 h</td>
<td>2.300 ml</td>
</tr>
<tr>
<td>Madi et al. [4]</td>
<td>2.5 h (75—240')</td>
<td>620 ml (200—1900 ml)</td>
</tr>
<tr>
<td>Beisse [5]</td>
<td>3.5 h (5.2 h in 1 subgroup of 30 neurologic patients)</td>
<td>870 ml (with use of self-saver)</td>
</tr>
</tbody>
</table>
Anterior spine surgery in recent thoracolumbar fractures: An update

Table 4 Neurological results of anterior decompression.

<table>
<thead>
<tr>
<th>Authors [ref.]</th>
<th>Incomplete pre-op deficit (n)</th>
<th>Neurologic improvement (n)</th>
<th>Gain in Frankel grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larson et al. [62]</td>
<td>46 unable to walk</td>
<td>29/46 able to walk</td>
<td>Not specified</td>
</tr>
<tr>
<td>Dunn [16]</td>
<td>40</td>
<td>40</td>
<td>Not specified</td>
</tr>
<tr>
<td>Kaneda et al. [10]</td>
<td>148</td>
<td>142</td>
<td>142: at least 1 grade</td>
</tr>
<tr>
<td>Mac Afee et al. [3]</td>
<td>42</td>
<td>37</td>
<td>37/42 at least 1 grade</td>
</tr>
<tr>
<td>Kostuik [18]</td>
<td>57</td>
<td>57</td>
<td>All at least 1 grade. mean 1.6</td>
</tr>
<tr>
<td>Transfeldt et al. [26]</td>
<td>43</td>
<td>20</td>
<td>32% at least 1 grade if operated before 2 yrs</td>
</tr>
<tr>
<td>Been [11]</td>
<td>10</td>
<td>9/10</td>
<td>9/10: 1 or 2 grades</td>
</tr>
<tr>
<td>Hass et al. [22]</td>
<td>19 grades A/B and 20 grades C/D/E</td>
<td>71% improved</td>
<td>50%: 1 grade</td>
</tr>
<tr>
<td>Sasso et al. [33]</td>
<td>33</td>
<td>30</td>
<td>30/33 at least 1 grade</td>
</tr>
<tr>
<td>Goutallier et al. [21]</td>
<td>20</td>
<td>18</td>
<td>Mean 1.3</td>
</tr>
<tr>
<td>Okuyama et al. [23]</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carl et al. [64]</td>
<td>26</td>
<td>26</td>
<td>Mean 1.3</td>
</tr>
<tr>
<td>Ghanayem and Zdeblic [17]</td>
<td>3 Frankel D</td>
<td>3 Frankel E</td>
<td>1</td>
</tr>
<tr>
<td>Schnee and Ansell [24]</td>
<td>17</td>
<td>16</td>
<td>12/17: 1 grade</td>
</tr>
<tr>
<td>Schulteiss et al. [7]</td>
<td>Not specified</td>
<td>Not specified</td>
<td></td>
</tr>
<tr>
<td>Madal et al. [4]</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

meta-analysis [25]), but can exceed 5 liters [21,26]. The accident-to-surgery interval impacts bleeding: in very early surgery (before 24–48h) fracture bleeding is hard to control, while if surgery is too late (after 25 days), nascent consolidation requires bone-bridge release which incurs further bleeding [20].

Material should be lateral, without contact with arterial vessels, as some cases of late aortic erosion by projecting plates or screws have been reported [21,27]. The material should therefore be such as to minimize projection (maximum plate thickness, 10 mm), without projecting relief. For some authors, this risk argues for a straight approach, to position the material at a distance from the aorta.

Pulmonary complications (atelectasia, pneumothorax, hemothorax or pneumopathy) occur in 5% to 15% of cases [4,5,19,20]. Their frequency and severity should be reduced by attention to lung re-expansion quality after closure [8], with systematic and effective pulmonary drainage in case of a transpleural approach or of leakage during re-expansion, while minimizing surgery time. Video-assisted techniques seem to be effective in limiting hemorrhage, but do not remove the risk of pulmonary atelectasia [4].

The problem of the anterior spinal artery

Certain French authors insist on medullary arteriography to select the side of approach, in order to conserve the intercostal artery from which the radiculomedullary (Adamkiewicz) artery originates, and which entails a theoretical risk of medullary ischemia in case of lesion [28]. No English-language teams, however, so much as mention an indication for this examination in traumatology. The risk thus seems to be slight (or non-existent?), since no neurologic aggravations were reported in 688 detailed postoperative neurological follow-up files. As its interest appears to be very hypothetical, we do not recommend undertaking preoperative medullary arteriography.

Impact of anterior decompression on neurological status in trauma patients

Fifty to 100% of patients achieve postoperative grade 1 on the Frankel scale, with mean recovery of around 1.3 grades (Table 4). There were no cases of neurologic aggravation in the 16 published series, and it is thus completely exceptional. Moreover, 35% to 70% of cases of total or partial functional sphincter impairment recover completely or partially [3,11,12,21].

Evolution of canal stenosis after anterior decompression

Mean preoperative canal stenosis was close to 50% in almost all series (Table 5); following corporectomy, CT assessed

Table 5 CT evolution of canal stenosis after anterior decompression.

<table>
<thead>
<tr>
<th>Authors [ref.]</th>
<th>Pre-op stenosis (%)</th>
<th>Post-op stenosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaneda et al. [10]</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>Sasso et al. [33]</td>
<td>68.5 (32–100)</td>
<td>Not specified</td>
</tr>
<tr>
<td>Schnee et Ansell [24]</td>
<td>48.7</td>
<td>Not specified</td>
</tr>
<tr>
<td>Aydín et al. [65]</td>
<td>41 (13–67)</td>
<td>6 (0–18)</td>
</tr>
<tr>
<td>Beisse [5]</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>Goutallier [21]</td>
<td>48</td>
<td>32 (on myelography)</td>
</tr>
</tbody>
</table>
Figure 6  T12 fracture, Magerl type C, with Frankel B para-
plegia. A. Pre-op myelogram. Horizontal slice No dural sheath
opacity due to medullary compression. B. Post-op control
Incomplete neurologic recovery (Frankel D paraplegia).

Deformity consolidation rate and evolution

Deformity consolidation rates range from 85% to 100%, with
a mean 10°—20° reduction in initial kyphosis (Table 6).
Secondary correction loss is systematically less then 5°.
Instrumental arthrodesis using an isolated anterior approach
thus seems to be effective against secondary recurrence of
kyphosis.

Functional results

Eighty to 95% of patients returned to work after their opera-
tion, 70 to 85% to their previous job [10,11,21—23]. Fifty to
85% reported no residual spine pain, while 1 to 5% reported
persistent disabling pain [10,11,17,21—23].

Indications for surgery on an anterior
approach in recent spinal trauma of the
dorsolumbar hinge

An anterior approach is to be recommended on mechanical
grounds, to repair anterior bone loss, and neurologically, to
release medullary compression by removing intracanal bone
fragments. It provides a one-shot solution: decompression by
corporectomy, reduction by anterior spinal reopening, inter-
or intrabody bone graft and, finally, plate osteosynthesis.
Neurologic recovery rates are slightly better than in pos-
terior surgery, with better spinal profile correction [29]. It
also involves a smaller number of instrumentally fixed levels:
following corporectomy, arthrodesis usually concerns three
vertebrae (two disks).

The prime drawback of the anterior approach lies in its
technical difficulty [7,19,30]. It tends to be more hemor-
rhagic than posterior surgery, even with minimally invasive
techniques. According to Verlaan’s meta-analysis, surgery
on an isolated anterior approach shows a lower rate of
postoperative neurological aggravation, at 0.2% versus 0.7%
for a posterior approach [25]. Certain contra-indications,
however, are to be borne in mind: morbid obesity, certain
chest pathologies inducing respiratory insufficiency (tho-
racic involvement with pulmonary contusion in multiple
trauma), pleural synechia (purulent pleurisy) or coagula-
tion disorder (DIVC). Certain traumatic lesions (irreducible
dislocation) are more obviously and easily reduced using a
posterior approach.

Indications for treatment depend on the patient’s neuro-
logical status, the acceptability or otherwise of the initial
deformity and the degree of medullary canal stenosis, but
also on the morphological and neurological evolutive
potential of the spinal lesion. For many authors, they also
follow from the limits of the posterior approach in terms
of the degree anterior spinal destruction, post-traumatic
kyphosis and canal stenosis.

The prime indication for an anterior approach in spinal
traumatology is incomplete neurologic deficit related to
medullary compression induced by canal stenosis which
cannot be managed using any other approach [22]. Decom-
pression is then based on corporectomy with associated
graft and osteosynthesis. According to Louis and Goutal-
dier, certain cases of loss of anterior spinal substance and
of canal stenosis of vertebral body origin call for an anterior
approach, even in the absence of any neurological compli-
cation [31].

Some 10% (607/6708) of cases of dorsolumbar spinal
trauma are operated on with an exclusively anterior
approach, and 5% (317/6708) with a combined approach
[25]. In terms of post-traumatic kyphosis, multiple trauma
rate and neurological complications, patients operated on
with an anterior approach would seem to have been the
more severe cases. There is too much uncertainty as to
Anterior spine surgery in recent thoracolumbar fractures: An update

be systematic, even in case of neurologic involvement [29].

 anterior stage and the laminectomy group. Laminectomy is no

 posterior approach without laminoarthrectomy or any ante-

 1995 SOFCOT symposium series [36], recovery was equiv-

 40% was associated with little opportunity for indirect decompression (Fig. 8).

 fragment despite only minimal kyphosis and loss of height, 

 considerable loss due to posterior displacement of a body

 fragment [36]. Some authors resect the fragment using

 percentage of iterative posterior displacement of the reduced 

 fracture allows the intracanal fragment to rotate, poorly 

 This ligamentotactic effect, however, requires PLL con-

 rupture allows the intracanal fragment to rotate, poorly 

 this whether to give priority to emergency treatment or

 surgery is not feasible in emergency. The question is

 with little opportunity for indirect decompression (Fig. 8).

 instabilty [12]. Saillant et al. further reported a high per-

 en currency which increases the post-traumatic 

 techniques using posteriorly introduced graft removers [40—45] 

 over associated with reduced secondary resorption of the 

 fragment [38,39]. The many anterior decompression tech-

 Operative ultrasound can assess medullary decompression quality 

 fragments adhering to the disks are par-

 Canal stenosis is mainly due to retraction of the poste-

 which is more efficiently corrected on a 

 direct anterior approach [10,16,18,23,32—34]. The frequ-

 of subsequent neurological recovery is equal to or 

 greater than 80%, and significantly correlated with the 

 quality of neuromeningeal decompression [2,3,13,19,32,34].

 Goutallier et al. demonstrated that postoperative myelo-

 graphic decompression of less than 40% was associated with 

 better recovery [13] (Fig. 7).

 Results with laminectomy vary greatly between reports. Surgery time and hemorrhage are increased, and there is a risk of dural breech and of neurologic sequelae [29,35]. Some authors consider it ineffective and beset by a risk of instability, non-union and secondary kyphosis [10,35]. In the 1995 SOFCOT symposium series [36], recovery was equivalent between the 25 patients with deficit treated on a posterior approach without laminoarthrectomy or any ante-

 rior stage and the laminectomy group. Laminectomy is no 

 doubt pointless in certain types of fracture, and should not 

 be systematic, even in case of neurologic involvement [29].

 Intracanal bone fragments adhering to the disks are par-

 totally repositioned by the ligamentotactic effect of the PLL 

 during restoration of vertebral body height and kyphosis 

 during restoration of vertebral body height and kyphosis 

 some, authors, preoperative ultrasound can assess medullary decompression quality 

 and orient surgery [47].

 Complications

 Indications for anterior surgery and neurological complications

 Canal stenosis is mainly due to retraction of the posterior vertebral wall, which is more efficiently corrected on a direct anterior approach [10,16,18,23,32—34]. The frequency of subsequent neurological recovery is equal to or greater than 80%, and significantly correlated with the quality of neuromeningeal decompression [2,3,13,19,32,34]. Goutallier et al. demonstrated that postoperative myelo-

 graphic decompression of less than 40% was associated with 

 better recovery [13] (Fig. 7).

 Results with laminectomy vary greatly between reports. Surgery time and hemorrhage are increased, and there is a risk of dural breech and of neurologic sequelae [29,35]. Some authors consider it ineffective and beset by a risk of instability, non-union and secondary kyphosis [10,35]. In the 1995 SOFCOT symposium series [36], recovery was equivalent between the 25 patients with deficit treated on a posterior approach without laminoarthrectomy or any anterior stage and the laminectomy group. Laminectomy is no doubt pointless in certain types of fracture, and should not be systematic, even in case of neurologic involvement [29].

 Intracanal bone fragments adhering to the disks are partially repositioned by the ligamentotactic effect of the PLL during restoration of vertebral body height and kyphosis correction, exerting indirect partial decompression. Total residual postoperative bone loss is usually less than 35% [32,37]. Certain fractures, however, are associated with considerable loss due to posterior displacement of a body fragment despite only minimal kyphosis and loss of height, with little opportunity for indirect decompression (Fig. 8).

 This ligamentotactic effect, however, requires PLL continuity, which is not what is generally found in case of posterior wall retraction equal to or greater than 50%. PLL rupture allows the intracanal fragment to rotate, poorly corrected by any ligamentotactic effect, and is moreover associated with reduced secondary resorption of the fragment [38,39]. The many anterior decompression techniques using posteriorly introduced graft removers [40—45] incur a risk of iatrogenic medullary lesion and require an enlarged approach which increases the post-traumatic instability [12]. Saillant et al. further reported a high percentage of iterative posterior displacement of the reduced fragment [36]. Some authors resect the fragment using an enlarged approach combining laminoarthrectomy then unilateral pediculectomy [32,46], while others consider residual stenosis after posterior reduction-osteosynthesis as an indication for a complementary anterior approach [7]. Peroperative myelography or, for some authors, preoperative ultrasound can assess medullary decompression quality and orient surgery [47].

 The accident-to-surgery interval issue

 Dorsolumbar hinge trauma surgery using an anterior approach is not feasible in emergency. The question is thus whether to give priority to emergency treatment or

 Table 6 Consolidation rate and evolution of kyphosis after anterior arthrodesis.

<table>
<thead>
<tr>
<th>Authors [ref.]</th>
<th>Material</th>
<th>Consolidation</th>
<th>Pre-op kyphosis</th>
<th>Postop kyphosis</th>
<th>Secondary reduction loss (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunn [16]</td>
<td>Dunn material</td>
<td>45/48</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Kaneda et al.  [10]</td>
<td>Kaneda plate</td>
<td>93%</td>
<td>Kyphosis: 19°</td>
<td>Kyphosis: 7°</td>
<td>1°</td>
</tr>
<tr>
<td>Sasso et al. [33]</td>
<td>Z plate ± cage</td>
<td>39/40</td>
<td>VK: 20°</td>
<td>VK: 8°</td>
<td>VK: 0°</td>
</tr>
<tr>
<td>Goutallier et al. [21]</td>
<td>Goutallier plate</td>
<td>100% (1 after early revision for disassembly)</td>
<td>RK: 12.5°</td>
<td>RK: −1°</td>
<td>RK: 3°</td>
</tr>
<tr>
<td>Okuvaama et al. [23]</td>
<td>Kaneda plate</td>
<td>100%</td>
<td>Kyphosis: 22°</td>
<td>Kyphosis: 11°</td>
<td>1°</td>
</tr>
<tr>
<td>Van Loon et al. [63]</td>
<td>Slot-Zielke material (1 rod)</td>
<td>92%</td>
<td>Kyphosis: 26°</td>
<td>Kyphosis: 14.5°</td>
<td>5.6°</td>
</tr>
<tr>
<td>Van Loon et al. [63]</td>
<td>Slot-Zielke material (2 rods)</td>
<td>100%</td>
<td>Kyphosis: 27.5°</td>
<td>Kyphosis: 12°</td>
<td>1.6</td>
</tr>
<tr>
<td>Dunn [16]</td>
<td>Dunn material</td>
<td>93%</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Kaneda et al.  [10]</td>
<td>Kaneda plate</td>
<td>100%</td>
<td>Kyphosis: 32°</td>
<td>Kyphosis: 11°</td>
<td>4°</td>
</tr>
<tr>
<td>Sasso et al. [33]</td>
<td>Z plate ± cage</td>
<td>24/25</td>
<td>Kyphosis: 16.8°</td>
<td>Kyphosis: 2.9°</td>
<td>Not specified</td>
</tr>
<tr>
<td>Goutallier et al. [21]</td>
<td>Goutallier plate</td>
<td>100%</td>
<td>Kyphosis: 21°</td>
<td>Kyphosis: 8°</td>
<td>‘Insignificant’</td>
</tr>
<tr>
<td>Okuvaama et al. [23]</td>
<td>Kaneda plate</td>
<td>100%</td>
<td>Kyphosis: 20°</td>
<td>Kyphosis: 6.6°</td>
<td>0.4°</td>
</tr>
<tr>
<td>Van Loon et al. [63]</td>
<td>Slot-Zielke material (1 rod)</td>
<td>100%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Van Loon et al. [63]</td>
<td>Slot-Zielke material (2 rods)</td>
<td>92%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Dunn [16]</td>
<td>Dunn material</td>
<td>100%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Kaneda et al.  [10]</td>
<td>Kaneda plate</td>
<td>100%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Been [11]</td>
<td>Slot-Zielke system</td>
<td>100%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Sasso et al. [33]</td>
<td>Z plate ± cage</td>
<td>100% (1 after early revision for disassembly)</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
<tr>
<td>Goutallier et al. [21]</td>
<td>Goutallier plate</td>
<td>100%</td>
<td>Kyphosis: 8°</td>
<td>Kyphosis: 0°</td>
<td>None ≥ 5°</td>
</tr>
</tbody>
</table>

SK: segmentary kyphosis; VK: vertebral kyphosis; RK: regional kyphosis.
to quality of decompression. Comparing neurological recovery after dorsolumbar hinge trauma with incomplete motor deficit of medullary origin treated by surgery using an anterior approach (i.e., with an interval of almost always at least a few days) versus a posterior approach (commonly performed in emergency) does not confirm any need for emergency intervention. In Kaneda’s series, the rate of neurological recovery (142/145 cases of at least 1 Frankel-grade improvement despite 143 of the 145 operations being performed more than 48 h after initial trauma) argued for a non-emergency attitude [12].

There is at present no statistical proof of the interest of emergency surgery in partial paraplegia of medullary origin secondary to dorsolumbar hinge fracture. While there

is no reason to delay surgery unduly, excellent neurological recovery has been reported for operations performed several weeks or months after initial trauma [2,8,26]. In MacAfee’s series [3], 70 thoracolumbar fractures with incomplete sensory and/or motor neurological deficit due to intracanal disk or bone fragment were treated by corpectomy decompression at a mean interval of 60 days (range, 1 day to 11 months); 37 of the 42 cases with motor impairment (88%) finally recovered by at least 1 Frankel grade; while 30 of the patients were initially unable to walk, 14 (47%) recovered the ability to walk independently.
Indications for anterior surgery and anatomic and mechanical sequelae of spinal trauma

Where surgery is indicated, some authors systematically perform an isolated anterior approach to reduce kyphosis and to graft and osteosynthesize unstable fracture [13,14]. Our own attitude is that the answers to the following questions determine the anatomic and mechanical indications for anterior surgery in dorsolumbar spinal trauma.
Is there a medullary compression threshold as of which corporectomy is mandatory whatever the neurologic status?
A reduction of 50% or more in canal diameter is the sign of medullary compression. Most authors then consider decompression logical, even without initial sensory-motor impairment, due to the risk of neurological aggravation in case of secondary displacement [48]. This 50% cut-off, however, is based on no statistical study. Okuyama et al. [23] assessed the stenosis threshold associated with medullary compression according to fracture level: 30% for T11-T12, 40% for L1 and 50% for L2. Hashimoto [1] likewise reported that the degree of stenosis inducing medullary lesion varied with fracture level: 35% for T11-T12, 45% for L1 and 55% for L2.

As Goutallier’s myelographic study showed [13], current assessment of sagittal spinal canal narrowing is very imprecise and systematically underestimates medullary compression. It is based on CT measurement of sagittal canal diameter; thus, only alterations in bone relief are assessed, neglecting the impact of intracanal hematoma and disc and ligament fragment displacement. Thirty years ago, Jelsma et al. came to the same conclusion on the basis of preoperative myelography which he performed to select optimal treatment [49]. There is thus no definite answer to the above question, although a 50% threshold is generally accepted, granted that the true stenosis value is considerably higher.

How to ensure and conserve satisfactory reduction of kyphosis induced by fracture?
The acceptable degree of kyphosis following reduction of dorsolumbar hinge fracture remains unclear. It is certain that kyphotic sagittal post-traumatic spinal imbalance may induce pain and damage to adjacent levels, which attempt to compensate for kyphotic malunion by means of hyperlordosis, but there is no consensus as to the acceptability limit for kyphosis: 15° [21,31], 20° [48] or 30° [11]? Given the range of factors involved in discal deterioration, it is not surprising that, at an individual level, the mid-to-long-term consequences of post-traumatic kyphosis should be unforeseeable. Traumatic damage to disks adjacent to the fractured vertebra may also affect the functional result, but is very variable, as demonstrated in discographic studies [31]. In contrast, diabolo fracture (Magerl A2) regularly involves severe discal lesion, penetrating the vertebral body fracture line (Fig. 9). The methodology of spinal morphology analysis partially accounts for these discrepancies. Deformity should always be correlated to its spinal location: kyphosis is to be judged more severe when it is in a level that would normally be in lordosis. Certain authors have drawn up graphs to deal with these variations: traumatic regional angulation (TRA) [36] or sagittal index [50]. In the 752 patients of the 1995 SOFCOT symposium [36], managed on a posterior approach, with a mean 34 months’ follow-up, there was a very significant difference in final TRA between the moderate-to-severe lumbalgia group and the group without pain or with pain not requiring analgesics. The authors indicated a 20° postconsolidation TRA threshold. According to its proponents, a sagittal index exceeding 10° requires correction of the deformity [47], while beyond 15° anterior spinal reconstruction is mandatory [50].

Traumatic kyphosis correction quality is better after anterior surgery, with less secondary correction loss [4,45,51]. Verlaan et al., in his meta-analysis, reported mean correction loss following anterior surgery of 3.1°, versus 7.6°, 4.9° and 8.6° for three different techniques using a posterior approach [25]. Despite mean preoperative kyphosis being 5° to 10° more severe in the anterior surgery group, results at end of follow-up were identical in all four treatment groups.
Anterior surgery following posterior reduction-osteosynthesis

Many series have shown that isolated posterior assemblies are insufficient, without repairing excessive anterior bone loss [43,47,52,53]. Despite improvements in posterior osteosynthesis techniques and material, combined reconstruction associating the anterior spine remains functionally more successful [35]. In Steib’s series, the follow-up Ossewstray score was 20% in the anterior graft group, versus 37% for an isolated posterior approach [35].

Anterior spinal reduction defects persist in some 20% of cases, causing non-union and reduction loss [54]. Using an initial posterior approach, many authors recommend complementary anterior surgery in case of excessively comminutive “burst” fracture [47], translation-rotation or dislocation (requiring primary reduction on a posterior approach, which is easier than an anterior approach) [7,22,55]. Many anterior graft techniques using a posterior approach have been described [45]. However, many studies, including Verlaan’s meta-analysis, concluded that transpedicular graft had no impact on long-term conservation of the kyphosis correction achieved by the posterior approach [25,56,57]. Nor does a long posterior assembly seem to guarantee long-term conservation of peroperative correction [36] and combined surgery thus seems logically more effective from a morphological point of view [58], especially in case of significant postoperative anterior bone loss. Thus, in a series of 70 dorsolumbar hinge fractures treated by reduction-osteosynthesis on a posterior approach, Steib reported that complementary anterior graft was required in more than 50% of cases (38/70) [35].

It should be borne in mind that the planned anterior second step is often (half of the time, in Parker’s series) finally not performed [59]. Onset of medical complications may logically account for this change in plans, but doubt may also arise simply as to the advisability of undertaking further surgery in a patient who seems to be well and showing neurological recovery. The indication for complementary anterior surgery should therefore be maintained when reasonable, so as to optimize the long-term result.

The conditions thus need to be defined in which the stability of the posterior synthesis is insufficient to achieve bone lesion consolidation or posteralateral arthrodesis fusion. According to Farcy et al., in case of significant loss of vertebral body bone capital, indicated by a sagittal index of 15° or more, anterior graft is required, as consolidation is otherwise impossible even with posterior reduction and stabilization [50]. The boss loss is to be filled with fibrous tissue, without restoring the integrity of the vertebral body architecture [50]. McCormack et al. [58] recommends the load-sharing classification, which takes account of the degree of comminution on sagittal CT reconstruction, of horizontal displacement of body fragments seen on horizontal slices and of the kyphosis corrected by the posterior reduct. Each item is graded 1 to 3, to give a global score ranging from 3 to 9 [58]; anterior surgery is mandatory as of a score of 7 [59]. According to Steib et al., if more than 50% of the posterior reduction is discal, the anterior spine should be reconstructed due to the frequency of secondary correction loss [35]. Conversely, in certain situations a complementary posterior stage should follow anterior surgery, especially when initial kyphosis exceeds 50° [17] or in C3 and most C2 fractures [19]. Improvements in osteosynthesis systems, however, seem to have pushed back the limits mechanical of isolated anterior assemblies [5].

When posterolateral arthrodesis is not indicated, due to a normal disk aspect and/or the risk of long-term consequences (L2 fracture in very young patients with lumbar discopathy risk factors), rigid reduction-osteosynthesis with a posterior approach followed by pure vertebral body graft may be considered, with systematic removal of the posterior material at about 1 year so as to restore lumbar spine mobility after consolidation of the fracture.

Contribution of vertebroplasty-cementoplasty techniques in dorsolumbar hinge fracture

First widely used in the management of osteoporotic collapse, percutaneous anterior spine reconstruction using cement (polymethyl methacrylate) or bone substitute (phosphocalcic cement) is increasingly applied in true post-traumatic vertebral body fracture (Magerl type A, including diabolo (A2) and burst (A3) fracture) [60,61]. It may be used in isolation or associated to posterior reduction-osteosynthesis. There is a risk of intracanal body fragment mobilization and of intracanal and/or extravertebral (including intravascular) cement leakage. It can be expected to progressively limit indications for anterior surgery when the aim is not decompression but vertebral body bone-loss repair following posterior reduction-osteosynthesis.

Conclusion

Anterior corporectomy-osteosynthesis-graft of dorsolumbar burst fracture restores near-normal anatomy, with effective neuromeningeal decompression. Neurological and functional results are good. Septic complications and postoperative neurologic aggravation are less frequent than in posterior surgery, but at the cost of greater bleeding, although this has been markedly improved by video-assisted surgery and new osteosynthesis materials.

Most of our knowledge of indications in dorsolumbar hinge fracture surgery is founded on retrospective data, with choice of treatment guided much more by each school’s history and beliefs [22] than by guidelines based on methodologically reliable comparative studies [25]. The technical difficulty of the procedure, its reputation as being aggressive [51] and its potential morbidity logically limited its development [5,22,51], which is now facilitated by minimally invasive video-assisted techniques that are far less iatrogenic than the classical techniques described 30 years ago [4]. The spread of these endoscopic techniques and the analysis of the limitations of isolated posterior osteosynthesis account for the extension of indications for double approaches, especially as the drawback of anterior surgery is its complexity when practiced in emergency [30], a situation in which we would not consider it a reasonable option.

Vertebroplasty adapted to spine trauma pathology should eventually replace indications for anterior surgery performed for purely mechanical purposes. The latter will, however, logically continue to play a role in the treatment of anterior medullary compression, whether or not induced by posterior reduction-osteosynthesis for complex
fracture with associated neurologic deficit of medullary origin. Jacques Sénéguess said, in 1988, of dorsolumbar fractures with neurologic lesions, that "a posterior approach is the technique of choice for those who do not have a regular practice of anterior spinal approaches, as the technical difficulties are less" [34]. In entire agreement with this point of view, we believe that, in order to manage traumatic vertebral lesions effectively, spine surgeons should now be able to adopt both anterior and posterior approaches, whatever the fracture level, using videoscopic or conventional techniques.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


