ORIGINAL ARTICLE

Minimally invasive management of thoraco-lumbar fractures: Combined percutaneous fixation and balloon kyphoplasty

F. Zairi a,*, C. Court b, P. Tropiano c, Y.P. Charles d, J. Tonetti e, S. Fuentes f, S. Litrico g, H. Deramond h, J. Beaurain i, P. Orcel j, J. Delecrin k, M. Aebi l, R. Assaker a, the French Society of Spine Surgery 1

a Department of Neurosurgery, Lille University Hospital, rue Emile-Laine, 59037 Lille, France
b Department of Orthopaedic Surgery, Le Kremlin-Bicetre, 94275 Paris, France
c Department of Orthopaedic Spine Surgery, Hospital Nord, 13915 Marseille, France
d Department of Orthopaedic Spine Surgery, Strasbourg University Hospital, 67091 Strasbourg, France
e Department of Orthopaedic Surgery, Grenoble University Hospital, 38043 Grenoble, France
f Department of Neurosurgery, La Timone Hospital, 13385 Marseille, France
g Department of Neurosurgery, Nice University Hospital, 06202 Nice, France
h Department of Radiology, Amiens University Hospital, 80054 Amiens, France
i Department of Neurosurgery, Dijon University Hospital, 21079 Dijon, France
j Department of Rheumatology, Lariboisiere Hospital, 75010 Paris, France
k Department of Orthopaedic Surgery, Nantes University Hospital, 44093 Nantes, France
l Department of Orthopaedic Surgery, Salem-Spital, Bern, Switzerland

Accepted: 21 June 2012

KEYWORDS
Kyphoplasty;
Percutaneous stabilization;
Load Sharing Score;
Fracture;
Thoraco-lumbar spine

Summary

Study design: Retrospective review of prospectively collected data.

Background: There is no consensus regarding the ideal treatment of thoraco-lumbar spine fractures without neurological compromise. Many surgical techniques have been described but none has proved its definite superiority. The main drawback of these procedures is directly related to the morbidity of the approach. As minimally invasive fixation combined with balloon kyphoplasty for treatment of thoraco-lumbar fractures is gaining popularity, its efficacy has yet to be established.

Purpose: The purpose of this study is to report operative data, clinical and radiological outcomes of patients undergoing minimally invasive management of thoraco-lumbar fracture at our institutions.

* Corresponding author. Department of neurosurgery, hôpital Roger-Salengro, boulevard Prof. Emile-Laine, 59000 Lille, France.
Tel.: +33 6 66 54 61 69; fax: +33 3 20 44 66 23.
E-mail address: fahed.zairi@gmail.com (F. Zairi).

1 94, rue Bobillot, 75013 Paris, France.
Introduction

The annual incidence rate of thoraco-lumbar fractures is 30 to 40 per 100,000 [1,2] and 70% of these fractures occur at the thoraco-lumbar junction, between T10 and L2. Despite their high frequency, there is no consensus regarding the ideal treatment. Although type B and C fractures of the AO-Magerl [3] classification require surgical treatment, neurologically intact type A fractures can be treated in different ways. During the past few decades, many surgical techniques of reconstruction and stabilization have been described involving anterior [4], posterior or both approaches [5]. The main disadvantage of these procedures is directly related to the morbidity of the approach. Some type A fractures can also be easily treated conservatively, with the risk of prolonged best rest complications and consequent kyphotic deformity, which can induce pain and disability [6]. Originally aimed to treat degenerative diseases [7], the percutaneous pedicle screwing technique has been progressively introduced for the treatment of thoraco-lumbar spine fractures [8]. This surgical technique avoids the drawbacks of conservative treatment with very limited morbidity by minimising iatrogenic soft tissue injury. Balloon kyphoplasty has been recently added to this minimally invasive strategy treatment [9] to enhance both reduction and mechanical support of the anterior column. As percutaneous screwing plus balloon kyphoplasty for treatment of thoraco-lumbar fractures gains popularity, its effectiveness has yet to be established. For the annual meeting of the French Surgical Spine Society (SFSC), we conducted a multicenter study to report operative data, clinical and radiological outcome of patients undergoing minimally invasive management of thoraco-lumbar fracture at our institutions.

Materials and methods

Demographic data

We retrospectively reviewed a series of 41 patients who underwent percutaneous kyphoplasty and stabilization for treatment of single-level fracture of the Thoraco-lumbar spine in 4 centres in France (Paris, Lille, Marseille and Strasbourg). All patients were neurologically intact. There were 20 males and 21 females with an average age of 50 years.

Methods: Forty-one patients underwent percutaneous kyphoplasty and stabilization for treatment of single-level fracture of the thoracic or lumbar spine. All patients were neurologically intact. There were 20 males and 21 females with an average age of 50 years.

Results: The mean follow-up was 15 months (3–90 months). The mean operative time was 102 minutes (range 35–240 minutes) and the mean blood loss was <100 mL. VAS was significantly improved from 6.7 to 0.7 at last follow-up. Vertebral kyphosis decreased by 16° to 7.8° postoperatively (P<0.001). Local kyphosis and percentage of collapse were also significantly improved from 8° to 5.6° and from 35% to 16% at last follow-up. Fifteen leaks have been identified, three of which were posterior; all remained asymptomatic. No patient worsened his or her neurological condition postoperatively.

Conclusion: Percutaneous stabilization plus balloon kyphoplasty seems to be a safe and effective technique to manage thoraco-lumbar fractures without neurological impairment.

Level of Evidence: Level IV. Retrospective study.

© 2012 Elsevier Masson SAS. All rights reserved.

Surgical procedure

The patient was positioned prone on a radiolucent table, allowing AP and lateral fluoroscopic control. The reduction was enhanced by external manoeuvres and by the use of iliac and chest rolls in order to increase lumbar lordosis. Prior to draping the patient, the midline and the projection of the pedicles were identified and marked on the skin. The first step of the surgical procedure was to perform the Kyphoplasty. Under AP and lateral fluoroscopic view, we performed the cannulation of both pedicles of the fractured vertebra. The both balloons were introduced in a convergent manner and parallel to the superior endplate. The reduction initiated during installation was completed by inflation of the balloons. Once reduction achieved, the cement was gradually injected, from the front to the back of the vertebral body, in order to strengthen the anterior part of the vertebral body. This was performed under strict control to detect any leakage in order to stop the filling if present. The second step performed percutaneous fixation. Pedicle screws were inserted under AP and lateral fluoroscopic control as described by Foley [7]. All patients underwent short segment stabilization (one level above and one level below) using the Sextant™ device (Sofamor Danek, Medtronic, USA). At the thoracic spine, the CD Horizon® Longitude™ device was preferred, because it allows adapting the bending of the rod to the spinal curvature (Sofamor Danek, Medtronic, USA). Sometimes, a loss of correction occurred during the deflation of the balloons. In this case, the balloons could be kept inflated until the reduction is maintained by osteosynthesis (Fig. 1).
Percutaneous fixation and kyphoplasty in thoraco-lumbar fractures management

Table 1 Summary of demographic data.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Level</th>
<th>Type</th>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Level</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>25</td>
<td>L2</td>
<td>A3.1</td>
<td>22</td>
<td>M</td>
<td>39</td>
<td>L1</td>
<td>A3.3</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>74</td>
<td>L1</td>
<td>A3.3</td>
<td>23</td>
<td>F</td>
<td>69</td>
<td>T12</td>
<td>A3.3</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>73</td>
<td>T3</td>
<td>A3.1</td>
<td>24</td>
<td>M</td>
<td>62</td>
<td>L3</td>
<td>A2.2</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>33</td>
<td>L2</td>
<td>B2</td>
<td>25</td>
<td>F</td>
<td>15</td>
<td>L1</td>
<td>A3.1</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>52</td>
<td>L3</td>
<td>B1</td>
<td>26</td>
<td>M</td>
<td>42</td>
<td>L1</td>
<td>B2</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>65</td>
<td>L1</td>
<td>A3.3</td>
<td>27</td>
<td>F</td>
<td>22</td>
<td>L1</td>
<td>B2</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>28</td>
<td>L1</td>
<td>A1.3</td>
<td>28</td>
<td>M</td>
<td>57</td>
<td>L1</td>
<td>A3.2</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>50</td>
<td>L1</td>
<td>A3.3</td>
<td>29</td>
<td>M</td>
<td>49</td>
<td>L1</td>
<td>B2</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>53</td>
<td>L2</td>
<td>A3.1</td>
<td>30</td>
<td>F</td>
<td>52</td>
<td>L1</td>
<td>A3.2</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>75</td>
<td>L1</td>
<td>A3.1</td>
<td>31</td>
<td>F</td>
<td>21</td>
<td>L2</td>
<td>B2</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>88</td>
<td>L4</td>
<td>A3.1</td>
<td>32</td>
<td>M</td>
<td>59</td>
<td>L1</td>
<td>A3.3</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>65</td>
<td>L2</td>
<td>A2.2</td>
<td>33</td>
<td>F</td>
<td>50</td>
<td>L1</td>
<td>A3.2</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>37</td>
<td>L4</td>
<td>A3.1</td>
<td>34</td>
<td>M</td>
<td>33</td>
<td>T12</td>
<td>A3.2</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>29</td>
<td>L2</td>
<td>B1</td>
<td>35</td>
<td>F</td>
<td>21</td>
<td>L1</td>
<td>A3.3</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>66</td>
<td>L1</td>
<td>A3.1</td>
<td>36</td>
<td>F</td>
<td>60</td>
<td>T12</td>
<td>B1</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>57</td>
<td>L1</td>
<td>A3.3</td>
<td>37</td>
<td>M</td>
<td>53</td>
<td>L5</td>
<td>A3.1</td>
</tr>
<tr>
<td>17</td>
<td>F</td>
<td>67</td>
<td>L1</td>
<td>A3.3</td>
<td>38</td>
<td>F</td>
<td>66</td>
<td>L1</td>
<td>A3.1</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>43</td>
<td>L1</td>
<td>A3.3</td>
<td>39</td>
<td>M</td>
<td>51</td>
<td>T5</td>
<td>A3.3</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>34</td>
<td>L1</td>
<td>A3.3</td>
<td>40</td>
<td>F</td>
<td>54</td>
<td>T12</td>
<td>A2.1</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>57</td>
<td>T12</td>
<td>A1.3</td>
<td>41</td>
<td>M</td>
<td>61</td>
<td>T10</td>
<td>A2.1</td>
</tr>
<tr>
<td>21</td>
<td>F</td>
<td>53</td>
<td>L1</td>
<td>A3.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Outcome assessment

Operative data (operative time, blood loss) and complications were reported. During the hospitalization period, clinical evaluation was performed to detect any neurological deficit or complication. Pain was quantitatively measured using the visual analogic scale (VAS), preoperatively, before discharge, at 3 months and at last follow-up. CT scan was performed before discharge to check the positioning of the device and to assess cement leakage. AP and lateral radiographs were performed preoperatively, before discharge, at 3 months and at last follow-up. Deformation in vertebral kyphosis, local kyphosis and percentage of anterior vertebral body collapse were measured (Fig. 2). For statistical data analysis, the Student t test was used. A P value less than 0.05 was considered statistically significant.

Results

The mean follow-up was 15 months (range 3—90 months) and no patient was lost to follow-up.

Figure 1 Intra-operative radiograph. The balloon is kept inflated until the completion of the osteosynthesis.

Figure 2 Measurement of vertebral kyphosis (white lines), local kyphosis (black lines) and percentage of collapse. (At = (B + C)/2. Percentage of collapse = (At-Am)/At).
Figure 3  Postoperative CT scan of a Magerl A3.1 fracture at T12 which confirm the well positioning of pedicle screws at T11 (A) and L1 (C) and the absence of cement leakage (B).

Operative date

The mean operative time was 102 minutes (range 35–240 minutes) and as the bleeding was very low (<100 mL), no blood transfusion was required. The average volume injected was 5.2 mL (range 3–9.5 mL). PolyMethyl-MethAcrylate (PMMA) cement was used in 31 patients, and phosphocalcic cement was used in ten patients. Cement leakage occurred during the procedure in 15 patients. Ten cases occurred in the PMMA group and five cases in the phosphocalcic group but the difference was not statistically significant (P=0.311). Most of the leaks were lateral (nine) or anterior (four); only three cases were posterior without neurological deterioration.

Clinical outcome

Pain was significantly improved. VAS dropped from 6.7 preoperatively to 2.4 at the day of discharge and 0.7 at the last follow-up. No patient worsened his neurological condition after surgery. We reported one wound infection, which required new operation without removal of the devices. Healing was obtained without sequelae. No other complication was reported.

Radiological outcome

Postoperative CT scan confirmed well positioning of the devices in all cases (Fig. 3). This exam confirmed cement leakage and specified their topography. Fifteen leaks have been objectified, three of which were posterior. None of these leaks were symptomatic. Based on the X-rays, all measured parameters were significantly improved (Table 2). Vertebral kyphosis decreased by 16° to 7.8° postoperatively (P<0.001). We reported a slight increase to 8.9° at last follow-up. Local kyphosis was also significantly improved postoperatively from 8° to 5.6° at last follow-up (P<0.01). We noted a very slight loss of correction during the follow-up period (Fig. 4). Similarly, the percentage of collapse has been significantly improved from 35% preoperatively to 16% at last follow-up.

Discussion

To date, there is no consensus regarding the ideal treatment of thoraco-lumbar spine fractures without neurological signs. Many surgical techniques have been described but none has proved its superiority over others [10]. The main limitation of these conventional techniques is directly related to the morbidity of the surgical approach. An anterior approach may be contra-indicated in overweight patients with bronchopulmonary disease, and exposes to respiratory, vascular and visceral complications [11]. A posterior approach requires a wide desinsertion of the paravertebral muscles, which leads to iatrogenic muscle denervation, elevated intramuscular pressure, ischemia, infections and increased postoperative pain [12]. Recent studies show no clear advantage when anterior is compared with posterior surgery [13]. Thus, most surgical teams use posterior instrumentation devices, because most of them are familiar with these techniques. Conventional posterior pedicle screw instrumentation often uses distraction forces to reduce kyphosis and restore vertebral body height. From biomechanical point of view, long segment instrumentation seems to be safer, as distraction forces are applied over the whole length of the instrumented spine [14]. Long segment stabilization has the disadvantage of blocking more mobile segments and is still associated with a high rate of loss of correction and instrumentation failure in case of significant comminution of the vertebral body [15]. The Load

| Table 2 Variations of each radiological parameter during the follow-up period. |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|
|                                 | Preop          | Postop         | 3 months       | Last follow-up |
| Vertebral Kyphosis (°)          | 16 (4,40)      | 7.8 (0,20)     | 7.9 (0,20)     | 8.9 (0,22)     |
| Local Kyphosis (°)              | 8 (–20,34)     | 5.1 (–27,23)   | 5.2 (–27,25)   | 5.6 (–20,30)   |
| Collapse (%)                    | 35 (15,66)     | 16 (2,44)      | 16 (2,44)      | 16 (2,44)      |
Percutaneous fixation and kyphoplasty in thoraco-lumbar fractures management

Sharing Classification [16] intends to precise the failure of the anterior column characterized by the comminution of the vertebral body. For fractures with high score, some surgeons advocate combined anterior and posterior approaches [17]. However, this treatment strategy is technically demanding, associated with significant morbidity and contraindicated in patients in poor general condition. In order to reduce iatrogenic lesions, new tools were developed to reduce the morbidity of the approach [18]. From the first experience using the percutaneous pedicle screw stabilization technique in the treatment of degenerative diseases, indications are extended for the treatment of thoraco-lumbar fractures. The most important criticism, made on this strategy, is the lack of spine fusion to ensure long-term stability. With regard to need for fusion, Wang et al. [19] conduct a prospective randomized study comparing clinical and radiological outcome of two groups of patients who underwent open posterior pedicle screw stabilization for the treatment of a thoraco-lumbar spine burst fracture (Magerl A3). The authors conclude that “the radiographic parameters are statistically better in the nonfusion group” when there is no clinical difference between the two groups. Results of this study legitimate the percutaneous stabilization technique for management of thoraco-lumbar spine fractures. Many authors report satisfactory clinical and radiological outcomes in the treatment of type A fractures [20, 21]. Although, no comparative study is conducted, results seem similar to the open standard technique with a significant reduction in morbidity. However, a short-segment posterior stabilization alone can cause a hardware failure or a significant loss of reduction with subsequent kyphotic deformity. Indeed, there is so much comminution in some fractures that they can represent a real risk of failure of short implant due to the lack of adequate anterior support. For this reason, Logroscino et al. [22] recommend to perform stabilization with long implants (two levels above and two levels below), with the drawback of reducing spinal mobility. It is actually well recognized that a Load Sharing Score greater than 6 should encourage the strengthening of the anterior column [16] in addition to the short-segment posterior stabilization. This can be achieved by a conventional or minimally invasive anterior approach [23]. Kyphoplasty allows strengthening of the anterior column, by the same minimally invasive posterior approach, limiting the overall morbidity of the procedure.

Fuentes et al. [9] report a series of 18 patients who underwent percutaneous short-segment stabilization and balloon kyphoplasty for the treatment of burst fracture (Magerl A3.1 and A3.3) with good clinical and radiological outcome. VAS dropped from 6.8 preoperatively to 1.1 at last follow-up. Local kyphosis was significantly improved from 14.4° to 5.2° at 2 year’s follow-up. Korovessis et al. [24] reported a series of 18 patients who underwent the same procedures for the treatment of burst fracture (Magerl A3) of the lumbar spine (L1-L4) with good outcomes. VAS decreased from 7.6 to 3.1 postoperatively. Local kyphosis improved from 16° to 2° postoperatively. According to these series, correction obtained in our study is also stable in time with a very slight loss of correction at last follow-up in terms of local kyphosis and vertebral kyphosis (Table 2). Strengthening of the anterior column obtained by Kyphoplasty appears to be effective over time, and the results at the final follow-up are equivalent to that obtained using an anterior approach [25].

Kyphoplasty have some risks. Cement leakage in the canal is previously reported in the literature. Creation of a cavity during inflation of the balloons reduces the injection pressure of the cement in comparison to simple vertebroplasty, which limits the risk of leakage [26]. Moreover, it is desirable to inject the cement as anteriorly as possible, which prevents the cement from entering the spinal canal and inducing mechanical compression and exothermic reactions involving nerve structures. Although there are only few clinical series about Kyphoplasty in the management of thoraco-lumbar spine fractures, risk of leakage increases with comminution of the vertebral body. Risk for posterior leakage increases with fracture lines at the posterior wall. In our series, a leak occurred in 13 cases out of which only

![Figure 4](image-url) Fracture at T12 (A) treated by balloon kyphoplasty and percutaneous stabilization. Postoperative lateral radiograph confirmed a good reduction with decrease of local kyphosis from 14° to 2°. We noted a slight increase of local kyphosis to 7° at 2 years’ follow-up.
three were posterior. Fuentes et al. report two cases (11%) of leakage outside of the canal, and Korovessis et al. report four cases (22%) of anterior leakage. Cement leakage is a common complication in this indication; however none are symptomatic. In our series, four patients underwent surgery for the treatment of A2 fractures without reported complication. However, such fracture is considered at increased risk of leakage mainly in the adjacent discs [27].

Pedicle screw stabilization can also induce neurological damage in case of misplacement. However, pedicle screws are inserted under strict lateral and AP fluoroscopic control, which ensures greater safety. We reported no case of screw misplacement, as confirmed by postoperative CT scan. Fuentes et al. reported a well-positioning rate of 100% while Korovessis et al. reported three cases of misplacement without clinical consequence.

No other mechanical complication is reported. Moreover, no case of deep infection is reported in our study or in the previous series. This can be explained by the small size of scars and absence of dead space, usually leading to such complications. Only one patient developed a wound infection, healed after debridement of the wound and initiation of adapted antibiotic therapy, without hardware removal.

Once the fracture heals, it is possible to remove the device by the same minimally invasive approach. This strategy is recommended for young patients to preserve mobility of adjacent levels.

Conclusion

Balloon Kyphoplasty followed by percutaneous fixation seems to be a safe and effective technique to reduce and stabilize type A thoraco-lumbar fractures without neurological signs. However, further studies with longer observation are required to support the longevity of this treatment and to precise its ideal indications.

Disclosure of interest

F. Zairi: no conflict in relation to the published manuscript.
C. Court: consultant for Medtronic, Spineguard, Spine Art.
J. Tonetti: consultant for Spineart.
P. Troiano: consultant for Synthes spine.
J. Beaurain: consultant for LDR.

Other authors have not given their declarations of interest.

References


