Evaluation of percutaneous surgery in the treatment of thoracolumbar fractures. Preliminary results of a prospective study on 65 patients

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KEYWORDS
Fractures;
Kyphoplasty;
Fixation;
Percutaneous;
Thoracolumbar spine

Summary

Introduction: We conducted a prospective, single-center, continuous study of patients operated for fractures unrelated to osteoporosis at the thoracolumbar junction level using percutaneous techniques. The aim of this study was to investigate the clinical and radiological outcomes of percutaneous techniques for these indications.

Patients and methods: This study included patients who underwent standalone balloon kyphoplasty surgery or combined with percutaneous posterior osteosynthesis in cases of associated distraction. The fractures were classified according to the Magerl classification. The patients were evaluated clinically (visual analog scale [VAS], the Oswestry Disability Index, and autonomy) and radiologically (vertebral kyphosis and height variations of the vertebral body) for 12 months.

Results: Sixty-five patients were included. The mean age at the time of the surgery was 45.4 years (range, 19–72 years). The main indications were A.1 fractures of L1. We noted 22% cement leakages, none having a clinical impact. In the overall series, the VAS at the lesion level improved from 5.5 (range, 3–8) preoperatively to 0.6 (range, 1–3) at 12 months. In all, 95% of the workers resumed their occupation. Traumatic kyphosis improved from 13.3\textdegree{} (range, 5–23\textdegree{}) before the surgery to 8.3\textdegree{} (range, 1–20\textdegree{}).

Discussion: The complication rate was low. The radiological results are comparable to those reported in the literature for other series with percutaneous surgery. Only the loss of the correction observed in the group undergoing standalone kyphoplasty with calcium phosphate cement led us to propose another type of treatment for these indications. This study must be continued

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Introduction

Fractures of the thoracolumbar spine are frequent [1] and severe lesions can result in profound changes in the patient’s quality of life [2]. There is no real consensus on managing these fractures, but the growth of new percutaneous surgical techniques has upset the traditional decision trees for therapy by proposing less restrictive treatment and earlier return to activities [3].

The general principle of the treatment of these fractures is to provide long-term correction of the vertebral deficiency resulting from injury so as to avoid kyphosis that will have negative clinical repercussions [4]. As such, the principle of kyphoplasty is to obtain reinforcement of the anterior column of the vertebra with cement after having reconstructed its anatomy with the joint action of the manner in which the patients are installed on the operating table and balloons [5]. Playing the role of an internal corset [6], percutaneous posterior osteosynthesis seems to be a good way to protect the posterior ligamentous complex (PLC) in cases with an associated distraction component.

This report presents the results of a prospective, single-center, continuous study of 65 patients who presented a non-osteoporotic fracture with no neurological deficit of the thoracolumbar spine, treated with standalone kyphoplasty or in association with percutaneous posterior osteosynthesis following the indications detailed below. The objective was to evaluate this series of patients clinically and radiologically so as to validate these percutaneous techniques in the designated indications and to propose possible improvements.

Patients and methods

Inclusion criteria

This prospective study involved a single-center, continuous, homogenous series comprising 65 patients. The patient inclusion period extended from January 2008 to November 2009.

This study included patients who had undergone a balloon kyphoplasty (Medtronic Sofamor Danek, Memphis, TN, USA) alone or in association with Sextant™ (Medtronic) percutaneous posterior osteosynthesis for the reasons retained: single fracture of the thoracolumbar spine (T11 to L2) with no disk or ligament instability. Patients were excluded if they presented fractures that appeared to be osteoporotic, with neurological complications during management, or presenting objective radiological rupture of the PLC such as dislocation of the joint facets or an increase in the interspinous space. In our opinion, this latter type of fracture remains an indication for open surgery with posterolateral arthrodesis so as not to expose the patient to the risk of material disassembly. Also eliminated from the study were Magerl [7] type A.33 fractures with comminution or an interfragment gap that was deemed too large (score ≥ 6 in the load-sharing classification [8]) as well as A.22-type butterfly-like fractures. For these fractures, the risk of extracorporeal cement leakage as well as the probable failure of mechanical reinforcement of the vertebral body with cement motivated the choice of corporectomy with expandable cage placement.

Indications and therapeutic modalities

All the patients in the series underwent kyphoplasty alone (49 cases) or associated with Sextant™ (Minimally invasive osteosynthesis (16 cases).

Kyphoplasty was used for fractures with bone involvement limited to the vertebral body caused by pure compression (Magerl type A). A solution was chosen such that for this type of fracture, long-lasting reconstruction of the vertebral body anatomy using kyphoplasty alone would be sufficient to reduce disk impaction [5], including in A3 fractures.

We based our indications of complementary percutaneous osteosynthesis on Vaccaro and the Spine Trauma Study Group’s work, who consider that PLC lesions have a central place in the therapeutic decision tree in fractures of the thoracolumbar spine [9,10]. Their Thoracolumbar Injury Classification and Severity Score (TLICS) [11] includes an “undetermined” status of this PLC. In practice, this corresponds to fractures caused by a distraction mechanism, with no involvement of the posterior bony arch (Magerl type B1) and with no radiological evidence of PLC rupture (Fig. 1). In this type of fracture, the principle of our treatment is to encourage healing of the PLC by protecting it with percutaneous osteosynthesis, after having reestablished the vertebral body anatomy with kyphoplasty.

In 69% of the cases, acrylic cement (bone cement V; Biomet Biologics, Warsaw, IN, USA) was used and in 31% of the cases calcium phosphate cement (KyphOś; Medtronic). The cement was chosen according to the patient’s age, with the upper limit of the calcium phosphate cement set arbitrarily at 40 years of age. The dose injected varied depending on each patient’s anatomy and the level and type of lesion.

The surgeries were performed in the same center by two senior operators and according to the same procedure: installation in the ventral decubitus position on bolsters, under general anesthesia, and with radioscopic guidance using two image intensifiers simultaneously, thus reducing the duration of surgery and limiting the risk of infection related to intraoperative handling. The trocar positioning technique was intentionally plunging and convergent for the kyphoplasty to obtain a single large cement cavity (Fig. 2) and following the pedicular axis for the percutaneous pedicular osteosynthesis. For the patients who received a Sextant™, the kyphoplasty was performed first so as
to restore the vertebral body anatomy before putting the osteosynthesis in place. In all cases, this consisted in a short montage with two polyaxial pedicular screws on either side of the fractured vertebra and two prebent stems.

The postoperative protocol included authorization of ambulation for the first time 24h after surgery depending on pain. The patients were generally discharged on day 2 for kyphoplasty alone and on day 4 if the Sextant™ was associated.

Patient follow-up

Clinical and radiological patient evaluation took place preoperatively, immediately postoperatively, and then at 6 weeks, 3 months, 6 months, and 1 year.

All patients were assessed for pain using the VAS and the Oswestry score [12]. The degree of autonomy was evaluated initially at the hospital when the patient stood for the first time and on discharge, then secondarily at the consultation by the mode of transport and whether or not home and work activities had been resumed. Finally, a graduated satisfaction questionnaire in four levels (poor, fair, good, excellent) was given to each patient at the last consultation.

The radiological analysis was performed using Spineview® software, based on digitized lateral spine x-rays. These radiographs were systematically taken preoperatively, intraoperatively (after installation on the table and at the end of the intervention), and postoperatively after standing for the first time, then at each visit. The vertebral defect correction was evaluated by vertebral kyphosis (VK) measurement of the height of the anterior (AH) and posterior (PH) column of the fractured vertebra that was reduced to the fixed value of the superior plateau of the subjacent vertebra (PL). These values were used to calculate the Beck Index [13], which is the ratio between the height of the anterior and posterior columns of the fractured vertebra. Finally, systematic postoperative CT was used to verify that the screws were properly positioned and to check for any cement leakage.

Statistical analysis

All the data were analyzed using SPSS 13 software. The Student t-test was used to compare quantitative variables on the overall series (65 patients) as well as the two subgroups: kyphoplasty alone (49 patients) and associated with percutaneous osteosynthesis (16 patients). These quantitative

Figure 2  Intraoperative study of kyphoplasty balloon positioning; a: balloons joining on the front (left, L2); b: balloons falling on the side; c and d: final result with a single large cavity of cement.
variables are described through their mean, standard deviation, and range. The two subgroups and the two types of cement were compared with the Wilcoxon test for matched series. The significance threshold was set at $P < 0.05$.

The different items were compared so as to demonstrate a statistically significant relation within homogenous groups in terms of pathology and treatment.

Results

Description of the population studied

During the inclusion period, 96 percutaneous interventions were performed in the department. Nine patients were lost to follow-up (six managed in another center and three not seen again in consultation). A total of 65 patients responded favorably to the inclusion criteria cited above. The characteristics of the population are summarized in Table 1.

The mean quantity of acrylic cement injected was 7.6 cc (range, 5—12 cc) versus 5.7 cc (range, 2—9 cc) for calcium phosphate cement; this difference can be explained by the much more rapid hardening properties of the latter.

The fracture mechanisms varied: 27 falls from a height, 20 traffic accidents, eight falls from a horse, six falls from a low height (four in a context of alcohol consumption and two caused by epilepsy), and four other etiologies.

The fractures involved the L1 vertebra in 31 cases (48%), T12 in 16 cases (25%), L2 in 12 cases (18%), and T11 in six cases (9%).

All the fractures treated with standalone kyphoplasty were Magerl type A fractures (Fig. 3) and those associated with a sextant were classified B1, as described above.

Table 1  Demographic characteristics of the population studied.

<table>
<thead>
<tr>
<th></th>
<th>Kyphoplasty alone</th>
<th>Kyphoplasty + Sextant™</th>
<th>Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>49</td>
<td>16</td>
<td>65</td>
</tr>
<tr>
<td>Sex ratio (M/F)</td>
<td>30/19</td>
<td>11/5</td>
<td>41/24</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>45.8 (19—72)</td>
<td>43.6 (24—51)</td>
<td>45.4 (19—72)</td>
</tr>
<tr>
<td>Type of cement (acrylic/calcium phosphate)</td>
<td>35/14</td>
<td>10/6</td>
<td>45/20</td>
</tr>
</tbody>
</table>

Complications

There were 14 cases (22%) of cement leakage: 43% upper disk leaks, 29% lower disk leaks, 21% anterior or lateral leaks, and 7% canal leaks. None of these leaks showed clinical manifestations, notably neurological. All of the screws showed a good pedicular trajectory on the follow-up CT scans on D1. Four postoperative complications occurred, all resolved with no sequelae after adapted treatment:

- one case of pulmonary embolus with thrombosis of a sural vein 48 h postoperative;
- a deep spondylodiscitis-type infection 2 months postoperative in a patient with relative immunodepression (obesity, type II diabetes, and long-term corticoid therapy for rheumatoid arthritis);
- left L2 cruralgia with probable pedicular breakage by the trocar during the kyphoplasty procedure;
- a postoperative hematoma in a patient who underwent osteosynthesis with the Sextant™ requiring revision for drainage at 72 h via two Wilte paraspinal approaches.

Clinical results

For the overall series, the VAS lesional score significantly improved ($P < 0.05$), decreasing from a preoperative score of 5.5 (range, 3—8) to 0.6 (range, 1—3) at the last follow-up (Fig. 4). The Oswestry score decreased from 17.6 (range, 2—42) at the first consultation to 4.1 (range, 0—12) at 1 year. At 1 year, there was no significant difference between the two subgroups ($P < 0.05$) for the clinical scores.

The patients first stood upright on D2 (range, D1—6) and were discharged on D3 (range, D2—7) for the standalone kyphoplasty procedure and D4 (range, D2—7) for those associated with osteosynthesis.

Figure 3  Distribution of fractures treated with kyphoplasty alone according to Magerl classification.

Figure 4  Visual analog scale (VAS) over time; Pré-op: preoperative.
Percutaneous kyphoplasty was used in the overall series, with a mean follow-up of 13.3 ± 6.1 months. In the kyphoplasty subgroup, the loss of correction over time was significantly greater (P < 0.05) in the patients having calcium phosphate cement (range, 3.8 ± 4.2) than those with acrylic cement (1.9 ± 4.8). This difference was not observed in the Sextant™ subgroup (Table 3).

The VK study in the cases of kyphoplasty alone according to the fracture type found a significantly greater absolute gain in correction at 1 year (P < 0.05) for A3 fractures (range, 6.1 ± 4.9), in which initial VK was greater, than for Magreri A1 fractures (range, 4.2 ± 5.2) (Table 3).

The analysis of the linear values of the lesioned vertebrae allowed us to objectify a 7% gain in height of the anterior column and a 13% gain in the Beck Index at the last follow-up. However, a 3% loss in height of the posterior column was observed (Table 5). There was no significant difference for these values between the standalone kyphoplasty and kyphoplasty with osteosynthesis subgroups (P < 0.05).

Discussion

Management of fractures of the thoracolumbar spine remains controversial. For a long time, the operator had only the choice between orthopaedic treatment or classical surgery. A literature search did not turn up any consensual guidelines on this subject [14–16]. However, most studies found better VK correction [4,17] and a shorter hospital stay [18] with surgical treatment, at the cost of a higher complication rate.

Percutaneous vertebral cementoplasty techniques (vertebroplasty and kyphoplasty) have been the subject of many publications over the past few years in the field of osteoporotic fracture management, for which they become a first-line treatment [19,20]. Studies conducted by Maestretti et al. [13] and De Falco et al. [21] have validated these techniques for compression fractures in young subjects. Oner et al. and Verlaan et al. [5,22] have demonstrated the advantage of kyphoplasty in reconstructing the anterior column complementary to short posterior instrumentation.

The objective of percutaneous posterior osteosynthesis was to reduce muscular injury, blood loss, and the...
hospital stay. Initially developed for degenerative surgery \[23\], teams such as Pelegri’s \[24\] and Rampersaud’s \[25\] demonstrated that these techniques had their place in traumatology. Finally, more recently, Fuentes et al. validated the association of kyphoplasty with percutaneous posterior osteosynthesis in the management of burst fractures \[26\].

The present study confirms the reliability of these surgical percutaneous techniques in the designated indications, since only four complications occurred, all resolved after adapted treatment. None of these complications was directly caused by the cement, even if the high rate of leakage to adjacent discs should encourage the search for the onset of discopathy, which was not evaluated in this study.

### Table 3

<table>
<thead>
<tr>
<th>Type of cement</th>
<th>PMMA</th>
<th>Tri-Ca++</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyphoplasty alone (n = 49)</td>
<td>Nb of patients</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Loss of VK</td>
<td>(1.9 \pm 4.8)</td>
<td>(3.8 \pm 4.2)</td>
</tr>
<tr>
<td>Kyphoplasty + Sextant(^\text{TM}) (n = 16)</td>
<td>Nb of patients</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Loss of VK</td>
<td>(1.9 \pm 2.1)</td>
<td>(2.2 \pm 1.9)</td>
</tr>
</tbody>
</table>

PMMA: acrylic cement; Tri-Ca++: calcium phosphate cement; NS: non-significant \((P > 0.05)\); S: significant \((P < 0.05)\).

### Table 4

<table>
<thead>
<tr>
<th>Type of fracture (\text{Magerl})</th>
<th>Age (years)</th>
<th>Cement (cc)</th>
<th>VK Preop (°)</th>
<th>POv VK (°)</th>
<th>VK M12 (°)</th>
<th>Gain in correction (°)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 (n = 28)</td>
<td>42.6 (19—72)</td>
<td>6.4 (2—12)</td>
<td>12.6 (5—21)</td>
<td>7.3 (−4 to 15)</td>
<td>8.4 (−1 to 16)</td>
<td>(4.2 \pm 5.2)</td>
<td>S</td>
</tr>
<tr>
<td>A3 (n = 19)</td>
<td>50.7 (20—70)</td>
<td>8.4 (4—12)</td>
<td>14.3 (8—20)</td>
<td>7.1 (0—15)</td>
<td>8.2 (0 to 17)</td>
<td>(6.1 \pm 4.9)</td>
<td>S</td>
</tr>
</tbody>
</table>

Preop: preoperative; POv: postoperative after the first verticalization; S: significant \((P < 0.05)\).
Other than treating only non-osteoporotic fractures of the thoracolumbar spine, the particularity of this study was the treatment of type A3 fractures with kyphoplasty alone, limiting the use of complementary percutaneous osteosynthesis to B1 fractures with no radiological evidence of PLC rupture so as not to load the PLC for the duration of healing.

The functional and subjective results were good, since at 1 year 95% of the active patients were able to resume their occupation either in their former position or in an adapted position. Of the patients who were not working (the unemployed, retired, or students), 92% were able to resume their daily activities at 1 year at the same level and 8% at a lower level. None took painkillers higher than step 2 on a daily basis for spinal pain at the lesional segment. It should be noted that there was no significant difference in terms of clinical scores between the kyphoplasty alone subgroup and the kyphoplasty + Sextant™ subgroup, confirming that this percutaneous osteosynthesis was minimally invasive.

The absolute VK gain was $5.1 \pm 4.7$, slightly less than what has been reported in the literature for other series using percutaneous surgical techniques (Table 6). This difference can be explained by the less severe initial lesions in the present series (lower VK) and by the considerable loss of correction observed in the subgroup with kyphoplasty including calcium phosphate cement. Thus, in the kyphoplasty + Sextant™ subgroup in which the initial lesions were more severe and/or no loss in correction depending on the type of cement was observed (Table 3), the absolute gain in VK was $6.7 \pm 2.6$. Independent of the type of cement, the gain in VK obtained by kyphoplasty was significantly less in the A1 fractures $(5.3 \pm 5)$ than in the A3 fractures $(7.2 \pm 4.9)$. Moreover, the loss of correction was identical with time between the two fracture types, which confirms that kyphoplasty without complementary osteosynthesis has a place in the management of A3 fractures. In the overall series, it was noted that loss of correction occurred in most cases during the first 45 days $(2.5 \pm 4.8)$, which led us to exclude weightbearing as well as driving during this period.

The osteosynthesis material was removed in seven patients (44%). In all cases, this material was removed through small incisions centered on the screws, as described by De Peretti’s team [28].

### Perspectives and improvements

The preliminary results of this study allowed several improvements to these techniques to emerge:

- since the in vivo resistance to compression of the two types of cement were similar [29], we attribute the loss of correction observed in the cases of kyphoplasty with calcium phosphate cement to an insufficient filling volume (5.7 cc versus 7.6 cc for the acrylic). Therefore, we suggest systematically associating percutaneous posterior osteosynthesis when this cement is used, mainly in cases of a large vertebral body volume, e.g., in L1 or L2 fractures in a large subject;
- use of percutaneous pedicular osteosynthesis ancillary instrumentation with monaxial screws and the possibility of bending stems such as the CD Horizon Longitude™ (Medtronic) or Viper™ (Depuy Orthopedics, Warsaw, IN,

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Anterior and posterior column height over time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop</td>
<td>Initial Fluoroscopy</td>
</tr>
<tr>
<td>AH/PL index</td>
<td>55(25–86)</td>
</tr>
<tr>
<td>PH/PL index</td>
<td>77(47–104)</td>
</tr>
<tr>
<td>Beck index</td>
<td>71(48–88)</td>
</tr>
</tbody>
</table>

Percutaneous surgery at the thoraco-lumbar junction
Table 6 Comparative table of the different series reported in the literature for percutaneous treatment.

<table>
<thead>
<tr>
<th>Patients ($n$)</th>
<th>Mean age (years)</th>
<th>Mean follow-up (months)</th>
<th>Type of fracture (Magerl)</th>
<th>VAS at last follow-up</th>
<th>Oswestry at last follow-up</th>
<th>PLC at last follow-up</th>
<th>Beck index gain (%)</th>
<th>Postop complications</th>
<th>Revisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our series</td>
<td>23</td>
<td>36</td>
<td>A, B, C</td>
<td>1.6</td>
<td>28</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pelegri et al. [24]</td>
<td>38</td>
<td>36</td>
<td>A, B, C</td>
<td>1.6</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fuentes et al. [26]</td>
<td>29</td>
<td>42</td>
<td>A, B, C</td>
<td>1.6</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fuentes et al. [27]</td>
<td>30</td>
<td>26</td>
<td>A, B, C</td>
<td>1.6</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maestrelli et al. [13]</td>
<td>18</td>
<td>30</td>
<td>A, B, C</td>
<td>1.6</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pelegri et al. [24]</td>
<td>15</td>
<td>36</td>
<td>A, B, C</td>
<td>1.6</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

USA) stems would make it possible to carry out reduction maneuvers by distraction between the screw-holding forceps before performing the kyphoplasty. In theory, obtaining an additional gain in correction would be possible with ligamentotaxis, even though the recent study by Blondel et al. [30] did not demonstrate this;

- use of fluoroscopic guidance for the kyphoplasty [31] and reliable placement of the pedicle screws [32,33], thus reducing operator exposure to radiation during these repeated percutaneous procedures [34];

- transpedicular cancellous bone grafting has not always proved to be effective, even as a complement to osteosynthesis [35]; therefore use of BMP cement [36] or self-locking metal implants inserted via the pedicular approach [37] are solutions that may respond to questions on how cement evolves over the long term;

- systematic access to MRI when in doubt concerning posterior ligamentous complex injury could rationalize the indications for complementary posterior osteosynthesis [38,39].

Conclusion

This prospective study of 65 patients has confirmed the value of these minimally invasive surgical techniques in our indications, notably the contribution of percutaneous pedicular osteosynthesis in cases of a distraction mechanism in absence of radiological evidence of PLC rupture.

In accordance with those reported in the literature, the radiological and clinical results obtained as well as the low rate of complications and the patients’ early return to autonomy has led us to increasingly disregard open surgery techniques, preferring these minimally invasive techniques for our indications.

However, the follow-up of this prospective remains short and must be continued over time so as to detect any appearance of late complications such as discopathy and to respond to the remaining questions on the long-term behavior of cement.

Disclosure of interest

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

References

Percutaneous surgery at the thoraco-lumbar junction


