Original article

Surgical treatment of thoracic spine fractures. Outcomes on 50 patients at 23 months follow-up

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\textbf{A B S T R A C T}

\textbf{Purpose:} The morphological and biomechanical features of the thoracic spine, together with its close proximity to the spinal cord, set it apart from other spinal segments. Management of thoracic spine injuries consists of achieving a reduction and an immediate and long-lasting stabilization of the spine while constantly protecting the central and peripheral nervous system. The aim of this study was to determine the best treatment for surgical thoracic spine fractures.

\textbf{Materials and methods:} We studied the baseline characteristics of 68 patients admitted to our neurosurgical department for one or several thoracic spine fractures between 2008 and 2010. We analysed on this group of patient the surgical management, complications and functional outcomes. We detailed the 2-years radiological outcome on 50 patients (23 months mean follow-up).

\textbf{Results:} The majority of patients underwent an extensive posterior arthrodesis bridging, on average, 5.3 vertebrae. The median time between diagnosis and surgery was 2 days and the median length of stay in hospital was 13.5 days. About 94% of hooks and 80% of pedicle screws were considered stable. Mean values of reduction and correction loss were similar (about 4.5\degree). We concluded to the superiority of extensive procedures and of pedicle screws fixation for the reduction and the maintenance of the correction by the end of follow-up. Functional data indicated daily discomfort and moderate pain.

\textbf{Conclusion:} A prospective study comparing the different procedures and instrumentations is needed to better define guidelines for the management of thoracic spine injuries.

\textit{Level of evidence:} Level IV.

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1. Introduction

Although traumatic vertebral fractures represent a small proportion of general traumatology, their socioeconomic impact is far superior to other traumatic pathologies [1].

Thoracic fractures represent 20\% to 30\% of vertebral fractures and, because of the great force of the impact, cardiovascular, pulmonary or neurological traumas are often associated. This spinal segment has very little mobility given its anatomical characteristics. Deformities in the sagittal plane are often less dramatic than in the lumbar spine. However, neurological complications are more likely because of the presence of the spinal cord throughout the segment and the small diameter of the spinal canal.

Several surgical techniques have been recommended, depending on the type and importance of the fracture. The common goal of all those procedures is to prevent spinal cord compression, and to immediately and sustainably stabilize the thoracic spine.

We carried out a retrospective monocentric study on surgical traumatic fractures of the thoracic spine treated between 2008 and 2010 in our institution. Demographic characteristics, preoperative and postoperative clinical-radiological data were analyzed with 2 years follow-up.

2. Material and method

Sixty-eight patients underwent surgery performed by 4 different senior spine surgeons for one or several thoracic spinal fractures (T1–T12).
2.1. *Initial assessment*

The pre- and postoperative neurological assessments were carried out using the American Spinal Injury Association (ASIA) score [2] (Fig. 1).

A postoperative CT-scan and a MRI were carried out for each patient. Fractures were classified according to the Magerl classification [3], the Thoracolumbar Injury Classification and Severity Score (TLICS) [4], and the Load Sharing Classification [5]. Vertebral angulations evaluation included vertebral kyphotic angle (VKA), Cobb angle (CA), and traumatic regional angulation (TRA) [6,7]. They were evaluated before surgery, during hospitalization, and at the follow-up time.

2.2. *Surgical technique*

Posterior surgery was performed for almost patients. Depending on the type of fractures, an anterior surgical approach was used.

Short-segment instrumentation procedures are defined as the immobilization of the vertebra above and below the fracture, and long-segment instrumentation procedures as the immobilization of at least 2 vertebrae above and 2 below the fracture. Long-segment instrumentation was performed when kyphosis angulation was too important. Hooks were implemented when the size of pedicle did not permit the insertion of a pedicle screw, or to increase the solidity of the montage.

2.3. *Imaging analysis*

The analysis of the position of the implants was analyzed on CT-scan, the reduction in the initial deformity and its maintenance over follow-up were evaluated on standard full spine radiographs, carried out during the postoperative period and at the end of the follow-up.

CT-scan evaluation of the position of the implants was based on the Youkilis classification [8], modified with an additional grade when the implant was located outside of the pedicle. An equivalent graduation for the hooks is proposed below.

2.3.1. *Pedicles screws*

Grade 1 corresponding in correct positioning, grade 2 in breach < 2 mm, grade 3 in breach > 2 mm, grade 4 in screw outside the pedicle. We added letter A for internal positioning, and letter B for external positioning.

2.3.2. *Hooks*

Grade 1 corresponding in correct positioning, grade 2 in bad positioning with good bone anchorage and grade 3 in bad positioning with bad bone anchorage.

2.4. *Functional analysis*

Functional and quality of life assessments were carried out with translated and validated versions of the Oswestry Disability Index [9] and SF-36 [10].

2.5. *Statistical analysis*

Continuous variables are summarized with medians and quartiles, and categorical variables with numbers and percentages. Comparisons between different procedures were achieved with non-parametric tests: Fisher’s exact test or the Wilcoxon test. The comparison between different time points was performed with respect of paired-data status. A P value of < 0.05 was considered as significant. Statistical analyses were performed with the software R (v 10.13/R Development Core Team [2011]).

3. *Results*

Sixty-eight patients (47 men and 21 women) underwent surgery for a total of 88 thoracic spinal fractures during the study period. Mean age was 45 years (range 17–77). The mean follow-up on the baseline population was 16 months (range 6 days–39 months). Cause of mechanism was motor vehicle accidents in 31 cases and falls in 37 cases. Among the 68 patients, 18 patients (26%) were lost to follow-up before 1 year, as a result of geographic remoteness from the referral center.

3.1. *Preoperative clinical and radiological data*

The preoperative MRI was normal for 22 patients. Thirty patients presented a T2 hypersignal within the spinal cord; 12 patients had an epidural hematoma attached to the fracture. Another fracture, not visible on the CT-scan, was found in four cases. Injury of posterior ligamentous complex was observed in 28 cases.

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**Table 1**

<table>
<thead>
<tr>
<th>Level</th>
<th>Angle</th>
<th>Preop (n = 68)</th>
<th>Postop (n = 68)</th>
<th>Difference pre-/postop</th>
<th>Follow-up (n = 50)</th>
<th>Difference postop/follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1–T12</td>
<td>VKA</td>
<td>15.3°</td>
<td>10°</td>
<td>−5.3° (P &lt; 0.001)</td>
<td>12.5°</td>
<td>+2.5° (P &lt; 0.005)</td>
</tr>
<tr>
<td></td>
<td>CA</td>
<td>20.8°</td>
<td>17.3°</td>
<td>−3.5° (P = 0.001)</td>
<td>21.6°</td>
<td>+4.3° (P &lt; 0.001)</td>
</tr>
</tbody>
</table>

**Instrumentation**

<table>
<thead>
<tr>
<th>Level</th>
<th>Angle</th>
<th>Preop (n = 68)</th>
<th>Postop (n = 68)</th>
<th>Difference pre-/postop</th>
<th>Follow-up (n = 50)</th>
<th>Difference postop/follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPC (47)</td>
<td>VKA</td>
<td>15.52°</td>
<td>9.01°</td>
<td>−6.51° (P &lt; 0.001)</td>
<td>10.95°</td>
<td>+1.94° (P = 0.02)</td>
</tr>
<tr>
<td></td>
<td>CA</td>
<td>21.85°</td>
<td>16.64°</td>
<td>−5.21° (P &lt; 0.001)</td>
<td>20.17°</td>
<td>+3.53° (P &lt; 0.001)</td>
</tr>
<tr>
<td>SPC (9)</td>
<td>VKA</td>
<td>14.89°</td>
<td>12.78°</td>
<td>−2.11° (P = 0.16)</td>
<td>20.5°</td>
<td>+7.72° (P = 0.08)</td>
</tr>
<tr>
<td></td>
<td>CA</td>
<td>16.83°</td>
<td>18.78°</td>
<td>−1.95° (P = 0.28)</td>
<td>35.5°</td>
<td>+16.72° (P = 0.14)</td>
</tr>
</tbody>
</table>

LPC: long posterior construct; SPC: short posterior construct; VKA: vertebral kyphotic angle; CA: Cobb angle; preop: preoperative; postop: postoperative.
3.2. Surgical management

The median time between injury and surgery was 2 days (range 0–30 days). The mean length of hospital stay was 18 days (range 4–80 days). Eighty-six fractures were treated with a unique posterior approach, one with a unique anterior approach and one with a combined approach. Two patients underwent cement injection with posterior osteosynthesis, and one patient underwent balloon kyphoplasty.

The mean number of instrumented vertebrae per fracture was 5.3 (range 1–11). Interventions details can be found in Table 1 for each category of equipment used.

3.3. Fracture classification

According to the Magerl classification, 40 fractures were classified as type A, 44 as type B, and 4 as type C. We classified the fractures into 3 groups (Fig. 2): fractures of the upper thoracic region from T1 to T2 (1 fracture); fractures of the middle thoracic region from T3 to T9 (61 fractures) and of the lower thoracic region from T10 to T12 (26 fractures).

The preoperative VKA was 16° and CA was 21°, the mean preoperative TLICS score was 5.6 (range 2–10).

3.4. Implants positioning analysis

The distribution of the 255 pedicle screws assessed under the modified Youkilis classification is found on Figs. 3 and 4. Of the 92 grade 3B and 4B screws, 48 were placed with the “in-out-in” technique.

One hundred and fifty-nine hooks were analyzed, of which 94.3% were considered stable (grade 1 and 2).

3.5. Correction of the initial and maintenance over follow-up (n = 50 patients)

Regarding the correction of the initial deformation and the maintenance of the deformity correction over follow-up, we excluded all patients who were followed up less than 12 months. Thus, 50 patients were evaluated with 23 months mean follow-up.

The correction of the initial deformation was established on the early postoperative radiographs (4 days after surgery on average). The mean reduction in the VKA and in the CA was 5.3° and 3.5°, respectively (P < 0.05). It was higher above T10 and lower below (Table 1).

The postoperative TRA was significantly lower for screws-only procedures than for hooks-only procedures, regardless of the length of the procedure (Fig. 5). No significant difference was found on the postoperative TRA in relation to the length of the procedure.

On the maintenance of the deformity correction, there was a significant loss of correction of 2.2° for the mean VKA and 4.5° for the mean CA. The mean correction loss for long posterior procedures was 1.93° for the VKA and 3.51° for the CA (P < 0.01). For hybrid long procedures, there was a mean CA loss of 5.71° (P < 0.01).

No correlation was observed between the fusion and the maintenance of the initial correction.

3.6. Functional data analysis (n = 31 patients)

The SF-36 and ODI were reported for 31 patients (Tables 2 and 3). Postoperative neurological status within the ASIA classification is detailed in Table 4.

Concerning the SF-36, the mean mental health score (MCS) was 42.6 points (range 12–62.2) and the mean physical condition score (PCS) was 39.6 points (range 19.5–63.7). No difference in quality of life was found between patients who underwent short or long-segment surgical procedures.

Regarding the ODI, the mean value was 29%, corresponding to moderate incapacity. Results are shown in Table 3.

As for the SF-36 data, values were not significantly different according to the length of the procedure. SF-36 and ODI Scores according to the ASIA classification are resumed in Table 2. We studied the quality of life, functional status and pain according to the postoperative deformity. The mean ODI score was 24.6 in patients with CA > 20° (n = 14) and 31.6 in patients with CA < 20° (n = 14). Regarding the SF-36, MCS in those subgroups was 41.3 and 37, respectively, and ODI was 41.6 and 45.6, respectively.

3.7. Complications

Seven patients were reoperated, 2 for early surgical site infection, 5 for implants misplacement and 1 patient had a neurological
deterioration secondary to the supra-laminar hooks C7 positioning close to the spinal cord.

4. Discussion

In this study, MRI data led us to modify the Magerl classification and the TLICS score in 6 cases (7%) who changed from A to B due to a serious injury of the posterior elements. The STIR sequence allowed, in particular, more sensitive analysis of the posterior ligamentous complex. Literature data shows that MRI can detect 40% of additional fractures compared to CT-scan alone. In 25% of cases, it changes the fracture grade of the Magerl’s classification [11].

The vast majority of the surgical procedures were performed through a posterior approach (97%). The rate of long-segment procedures was 74%, with an average of 5.3 vertebrae included. In the Reinhold meta-analysis [12], anterior approaches represented 7.3% of the “thoracic fractures” subgroup. However, as recommended by the Load Sharing Score, supplements by the anterior approach enable to reduce secondary kyphosis and pains, and to improve neural release and fusion [13].

Fig. 4. Examples of implants classified according to the modified Youkilis classification. A. Grade 1. B. Grade 2A. C. Grade 4A (left) and 4B (right). D. Grade 4B way “in-out-in”. E. Grade 1 (right) pedicular hook, grade 2 (left). F. Transverse process hook grade 3.

Fig. 5. Immediate postoperative traumatic regional angulation (TRA) according to the type of surgery (A), or the type of instrumentation (B). LPC: long posterior construct; SPC: short posterior construct.
Regarding the position of implants, 80.4% of screws were considered acceptable (grades 1, 2, 3 B and 4B in-out-in). Hooks were considered stable (grade 1 and 2) in 94% of cases. Our analysis of the literature found a highly variable rate of pedicle breach, between 15.9% and 54.7% without peroperative X-rays [14] and up to 6% for navigation techniques [15]. The rate of correct positioning is about 60% with conventional techniques [16]. Several meta-analyses comparing the precision of implant placement according to various techniques [17] found that navigation techniques tend to be superior compared to non-navigated techniques [15], with a superiority of 3D CT-scan navigation over fluoroscopy 2D or 3D [17].

In our study, we found a significant difference between short and long-segment procedures as far as the correction and maintenance of this correction were concerned.

Indeed, the comparison of reductions in CA with these two types of procedures showed a positive difference of about 7° for long-segment procedures. Similarly, the values of postoperative TRA were significantly smaller in the “screws” group than in the “hooks” group, showing that the reduction is better with the use of pedicle screws and long procedures. The analysis of the correction maintenance over follow-up found a mean correction loss over the entire spine of 2.2° for the VKA and 4.5° for the CA. We found a difference in mean correction loss of about 1° between short and long-segment procedures, with no obvious difference within the long-segment procedure group according to the type of implant placed. Indeed, the mean increase in CA at the end of follow-up was 3.5° for long procedures versus nearly 13° for short procedures.

Some authors relate this kyphosis to disc degeneration [18]. We agree with this analysis as we noticed in all groups that the correction loss was more important on CA than on VKA angles. Moreover, fusion did not lead to a decreased kyphosis rates, suggesting that this kyphosis appears on soft-tissue.

Literature data report a late kyphosis rate between 3° and 10°, corresponding to an average correction loss between 0% and 50%, depending on the type of procedure [19].

A recent meta-analysis of 132 articles on fractures compared different surgical approaches [20]. Results on the reduction gave a gain of CA between 13° and 15°, although loss of correction after follow-up was between 3° and 7°.

The mean SF-36 score shows a higher physical and mental disability than standard values of an uninjured population. Standard values were 50.5 ± 9 for the PCS, and 51.7 ± 9.1 for the MCS [21]. Fisher et al. gave an average score for the American population with chronic back pain of 43.14 ± 11.56 for the PCS and 46.89 ± 11.73 for the MCS. In his series of 27 patients who had surgery for thoracic spinal fractures, Fisher found a mean PCS score of 35.89 and a mean MSC score of 56.43 [22]. Surprisingly, patients with total deficiencies obtained a far higher MCS score. Despite their handicap, these patients recovered a mental health equivalent or even superior to non-disabled patients.

The mean ODI for a “healthy population” is 10.2% [9]. In our population, our value of 29%, corresponding to moderate disability, is clearly lower than in the population with chronic back pain (43.3%). The ODI was higher with partly deficient patients than with other patients.

5. Conclusion

The analysis of the maintenance of the deformity reduction shows an important and significant loss over the follow-up. Consequently, the restitution of the anterior column must be considered more frequently. However quality of life was not different according to the initial deformity. An analysis of sagittal parameters as well as a long-term functional assessment would be useful to study, in particular, secondary disc degeneration.

The functional assessment mentions a moderate daily discomfort, lower than with chronic back pain for example.

The improvement in the management of these patients lies in the systematization of preoperative CT-scans together with more frequent MRI and full spine X-rays on the one hand, and more quality of life surveys in order to detect secondary deformities and functional failures during follow-up on the other hand.

Disclosure of interest

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

References


