Minimally invasive posterior transforaminal lumbar interbody fusion: One-year postoperative morbidity, clinical and radiological results of a prospective multicenter study of 182 cases

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A B S T R A C T

Introduction: Interbody fusion is the gold standard treatment for the management of numerous diseases of the spine. Minimally invasive techniques may be more beneficial than conventional techniques. The main goal of this study was to report the one-year postoperative results of a series of posterior lumbar interbody fusions by a minimally invasive technique in relation to improvement in functional outcome, interbody fusion and morbidity.

Materials and methods: Between January 2012 and May 2013, 182 patients treated by minimally invasive posterior transforaminal lumbar interbody fusion (TLIF) were included in this prospective multicenter study. Clinical assessment was based on a comparison of the preoperative and one-year postoperative Oswestry (ODI), SF-12 and Quebec Scores and the Visual Analog Scale (VAS). Surgical and postoperative follow-up data were evaluated. Radiological assessment was based preoperative and one-year postoperative full spine teleradiographs. Interbody fusion at one-year was systematically evaluated by CT scan.

Results: One hundred and eighty-two patients were included, mean age 58.9 years old. Surgery lasted a mean 101 minutes, mean preoperative bleeding was 143 mL, and mean radiation exposure was 247.4 cGy/cm². The rate of postoperative complications was 7.7%. The ODI, the Quebec Score, the SF-12 and the VAS were all significantly improved at one-year (P < 0.0001). The rate of fusion was 72.6% at the final follow-up. There was no significant difference in functional outcome between patients with and without fusion.

Discussion: The one-year postoperative radiological results and functional outcome of minimally invasive posterior lumbar fusion are satisfactory. The benefits of this minimally invasive approach are mainly found in the first 6 postoperative months. Successful radiological interbody fusion was not correlated to functional outcome at the final follow-up.

Level of evidence: IV.

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1. Introduction

Posterior interbody fusion is the gold-standard technique for the management of numerous diseases of the spine. The additional benefits of minimally invasive short lumbar interbody fusion have been studied for several years [1]. Different studies have reported positive results including reduced consumption of postoperative analgesics [2] or a shorter hospital stay [3]. However, the long-term results as well as the time to return to work have been less extensively studied [4]. Nevertheless, compared to conventional techniques, minimally invasive techniques are associated with a problem of perioperative radiation of the patient and the medical team [5].

The goal of this prospective multicenter non-randomized study was to evaluate the results of minimally invasive lumbar fusion associating interbody fusion with posterior fixation. The main goal
was to report the one-year postoperative outcome of this surgical procedure in terms of improved quality of life scores, interbody fusion and morbidity. The secondary goals of this study were to compare the functional outcome in patients with and without fusion at one year and look for risk factors of poor functional outcome.

2. Materials and methods

2.1. Design of the study and inclusion criteria

One hundred and eighty-two patients were included in this prospective multicenter non-randomized study between January 2012 and May 2013. An informed consent form was available for each patient.

Inclusion criteria were all patients over the age of 21 who required one or two stage posterior lumbar fusion for different indications (degenerative or stenotic spondylolisthesis, recurrent disc herniation, degenerative discopathy, foraminal stenosis or extraforaminal disc herniation). Patients from 3 centers in France were included in the study.

2.2. Surgical technique

All patients underwent surgery by posterior approach according to the technique described by Wiltse et al. [6]. Surgery was performed on the side where the patient had reported the most severe radiculalgia. After identifying the level of injury by fluoroscopy, a series of dilators were positioned before placing a tubular retractor to expose the articular processes, the pars interarticularis and the intervertebral space.

Transforaminal lumbar interbody fusion (TLIF) was then performed [7]; two pedicle screws were placed on the same side as the surgical incision then an interbody cage was placed. Different types of grafts were used depending on the surgeon's normal practice (iliac crest, bone graft substitute, bone morphogenetic protein [BMP]).

A contralateral pedicle screw was used in certain cases; thus there were three techniques in this series:

- either minimally invasive screw fixation by a 2nd Wiltse approach associated with a posterolateral graft (Fig. 1);
- percutaneous graft fixation [8];
- or no contralateral screw fixation, which is a technique called UNILIF (Fig. 2).

2.3. Clinical assessment

The preoperative and one-year postoperative clinical assessment included general information (professional activity, smoking, BMI, history of spine surgery), and self-assessment questionnaires. The following quality of life scores were analyzed: the SF-12 score, the Quebec Score, the Oswestry Score (ODI) and the lumbar-VAS and spinal-VAS (VAS).

Surgical data were also recorded (amount of bleeding, length of surgery and radiation exposure). All postoperative mechanical, infectious and neurological complications as well as revision surgeries were noted.

2.4. Paraclinical assessment

The preoperative and one-year postoperative imaging tests included AP and lateral teleroadiographs of the spine. These were used to measure pelvic parameters [9], lumbar lordosis, thoracic kyphosis, segmental discal lordosis, and to look for the development of any associated syndromes. The global sagittal balance was measured by the spinal tilt and the spino-sacral angle [10].

CT scan was systematically performed at the one-year postoperative follow-up to evaluate interbody fusion according to the Lenke Score [11]. This score, based on CT data, evaluates interbody fusion of the anterior spine in 4 stages.

2.5. Method of data collection

Demographic and radiographic data were entered into a common database (KEOPS®, Société de mesure et d'analyse de l'imagerie ostéo-articulaire, Lyon, France) from the preoperative consultation to the one-year postoperative assessment. Quality of life questionnaires were filled out directly by the patient.

2.6. Statistical analyses

Statistical analyses were performed by an independent observer with SPSS software. The relationship between the variables was evaluated by parametric tests (Student t test and Chi²) after confirming that the distribution was normal. P < 0.05 was considered to be significant. The odds ratio was used to quantify the
relationship between a subgroup of patients and the presence of different factors influencing the results.

3. Results

3.1. Demographic and surgical data

A total of 182 patients, mean age 58.9 years old (SD = 13.9) and mean BMI 25.9 (SD = 3.8) were included in the study. The male/female ratio was 0.89 (86 men/96 women). The different characteristics of the population are summarized in Table 1.

The indications for surgery were distributed as follows: 44 foraminal stenoses, 63 degenerative spondylolisthesis, 25 stenotic spondylolistheses, 26 recurrent disc herniations, and 24 extraforaminal disc herniations.

Single or two-stage fusion was performed in a total of 201 discs with posterior unilateral lumber interbody fixation (UNILIF) in 96 discs. Two-stage fusion was performed in 19 cases.

Surgery lasted a mean 101 minutes (SD = 24.9), mean preoperative bleeding was 143 mL (SD = 108.9), and mean radiation exposure was 247.4 cGy/cm² (SD = 230.1).

The rate of postoperative complications was 7.7%, including 5% requiring surgical revision (Table 2). A surgical site infection developed in one patient (0.6%) and no dural tears were reported.

### Table 1
Demographic data of the series.

<table>
<thead>
<tr>
<th>Profession</th>
<th>Patients (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>73</td>
<td>40.1</td>
</tr>
<tr>
<td>AT</td>
<td>64</td>
<td>35.2</td>
</tr>
<tr>
<td>Non-active</td>
<td>45</td>
<td>24.7</td>
</tr>
<tr>
<td><strong>Tobacco</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td>47</td>
<td>25.8</td>
</tr>
<tr>
<td>Non-smoker</td>
<td>135</td>
<td>74.2</td>
</tr>
<tr>
<td><strong>Indication</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foraminal stenosis</td>
<td>44</td>
<td>24.2</td>
</tr>
<tr>
<td>Degenerative SPL</td>
<td>63</td>
<td>34.6</td>
</tr>
<tr>
<td>Stenotic SPL</td>
<td>25</td>
<td>13.7</td>
</tr>
<tr>
<td>Recurrent HDL</td>
<td>26</td>
<td>14.3</td>
</tr>
<tr>
<td>Extraforaminal HDL</td>
<td>24</td>
<td>13.2</td>
</tr>
<tr>
<td><strong>Level of fusion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3-L4</td>
<td>18</td>
<td>9.9</td>
</tr>
<tr>
<td>L4-L5</td>
<td>95</td>
<td>52.2</td>
</tr>
<tr>
<td>L5-S1</td>
<td>50</td>
<td>27.5</td>
</tr>
<tr>
<td>Two stage</td>
<td>19</td>
<td>10.4</td>
</tr>
</tbody>
</table>

3.2. Clinical evaluation

The mean preoperative ODI was 44.9 (SD = 15.9), the mean Quebec Score was 50.9 (SD = 204), the mean VAS-L 5.1 (SD = 1.9) and the mean VAS-R was 5.2 (SD = 1.8) (Table 3).

At the one-year postoperative assessment the ODI, the Quebec Score, the SF-12, the VAS-L and the VAS-R (Table 3) had all significantly improved (P < 0.001).

The subgroup analysis of the fusion (Lenke 1 and 2) versus non-fusion (Lenke 3 and 4) groups did not show any significant difference in functional outcome at 1 year. Tobacco consumption was more frequently associated with the non-fusion group with an odds ratio of 2.16 (0.96–4.86).

### Table 2
Postoperative morbidity.

<table>
<thead>
<tr>
<th>Complications with revision</th>
<th>Patients (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic inaccurate position</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Nonunion</td>
<td>5</td>
<td>2.7</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>Bleeding</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>Other complications without revision</td>
<td>5</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14</td>
<td>7.7</td>
</tr>
</tbody>
</table>

### Table 3
Preoperative and 1 year postoperative functional scores and radiographic results.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative Mean</th>
<th>Preoperative SD</th>
<th>At 1 year Mean</th>
<th>At 1 year SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODI</td>
<td>44.9</td>
<td>15.9</td>
<td>18.7</td>
<td>15.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Quebec</td>
<td>50.9</td>
<td>20.4</td>
<td>27.8</td>
<td>20.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SF-12 (PCS)</td>
<td>31.3</td>
<td>7.5</td>
<td>42.8</td>
<td>9.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SF-12 (MCS)</td>
<td>39.3</td>
<td>11.6</td>
<td>47.6</td>
<td>10.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>VAS-L</td>
<td>5.1</td>
<td>1.9</td>
<td>3.1</td>
<td>1.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>VAS-R</td>
<td>5.2</td>
<td>1.8</td>
<td>3</td>
<td>2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pelvic incidence</td>
<td>56.4</td>
<td>12.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvic version</td>
<td>37.5</td>
<td>8.5</td>
<td>37.4</td>
<td>9.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lumbar lordosis</td>
<td>–53.4</td>
<td>12.1</td>
<td>–51.9</td>
<td>9.6</td>
<td>0.03</td>
</tr>
<tr>
<td>Thoracic kyphosis</td>
<td>44.6</td>
<td>12.8</td>
<td>45.7</td>
<td>11.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Spinal tilt</td>
<td>86.6</td>
<td>2.9</td>
<td>86.9</td>
<td>2.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Spino-sacral angle</td>
<td>125.4</td>
<td>8.9</td>
<td>124.4</td>
<td>7.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lordosis L5-S1</td>
<td>–6.9</td>
<td>5.2</td>
<td>–7.3</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Lordosis L4-L5</td>
<td>–8.3</td>
<td>6.6</td>
<td>–7.1</td>
<td>5.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lordosis L3-L4</td>
<td>–7.4</td>
<td>2.5</td>
<td>–6.2</td>
<td>2.6</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Ns: not significant (P > 0.05).
3.3. Radiological assessment

Mean pelvic incidence was 56.4° (SD = 12.6°), lumbar lordosis was −53.4° (SD = 12.1°). Sagittal balance was good in patients in the series with a mean spino-sacral angle of 125.4° (SD = 8.9°). Mean segmental disc lordosis of the operated discs was −6.9° (SD = 5.2°) for L5-S1, −8.3° (SD = 6.6°) for L4-L5, de −7.4° (SD = 2.5°) en L3-L4.

There was no statistically significant difference between the preoperative and one-year postoperative results except for mean lumbar lordosis which went from −53.4° to −51.9° (P = 0.03) and mean L3-L4 segmental discal lordosis which went from −7.4° to −6.2° (P = 0.04).

Assessment of interbody fusion at 1 year showed Lenke stage 1 in 34.6%, stage 2 in 38%, stage 3 in 23.5% and stage 4 in 3.9%.

4. Discussion

The goal of this multicenter prospective study was to analyze the functional and radiological outcome of a cohort of 182 patients who underwent minimally invasive posterior transforaminal lumbar interbody fusion.

4.1. Perioperative morbidity

The results of this study are similar to the results in the literature:

- the mean duration of surgery (101 minutes) is comparable to results reported in the literature [8]. It is higher during the early procedures, estimated by Lee as approximately 40 procedures [12] before stabilizing;
- mean surgical bleeding (146 mL) is in the low range compared other series [4,8];

Our rate of complications (7.7%) was slightly higher than that reported by Wu et al. [13]. However minimally invasive surgery has clearly been shown to be better than conventional surgery with an overall rate of complications of 7.5% and 12.6% respectively. No complications specific to the minimally invasive approach have been reported, however there was a marked decrease in the frequency of dural tears and infections [14]. The latter has a significant influence on medical costs [15]. In the present study only one case of postoperative infection was reported or 0.6%.

In a prospective series of 100 consecutive cases, Tsahatsaris and Wood did not report any infections or dural tears. On the other hand he reported inaccurate screw placement or migration of the interbody cage in 2.5% each [16]. We had similar results in our series with 5 revisions for symptomatic inaccurate screw placement (0.8%).

4.2. Radiation

Radiation exposure is still an important problem in minimally invasive surgery, both for patients and medical personnel [13]. Bronsard et al. report that radiation exposure during a procedure with short percutaneous internal fixation (4 pedicle screws) is 3 times greater than a conventional procedure [17]. However this must be placed in perspective because the effective dose of a CT scan is 21 times higher than conventional internal fixation and 6 times greater than percutaneous internal fixation.

We chose to perform a systematic postoperative CT scan which has become general practice but which is open to criticism [18].

4.3. Clinical benefits

The minimally invasive approach is beneficial in the initial period and contributes to faster functional recovery [19,20]. However after 6 months, there was no significant difference between the two techniques [13].

We evaluated the proportion of patients who were found to have a marked intradividual clinical benefit after 1 year according to criteria by Glassman et al. [21]. In particular this benefit is defined by a decrease in the ODI of at least 18.8 points, a decrease in the VAS-L of at least 2.5 points or a decrease in VAS-R of at least 2.5 points. The results of this study showed a clinically significant improvement of 74% for the ODI, 70% for the VAE-L and 80% for the VAE-R.

4.4. Segmental lordosis and sagittal balance

Sagittal balance was not significantly changed in the patients in this study at the one-year follow-up. Overall pelvic and spinal parameters were correlated [22], even though mean lumbar lordosis at 1 year was significantly reduced (−53.4° vs. −51.9° = 0.03). Interbody cages implanted by the posterior approach were not shown to influence lordosis in our series because segmental lordosis was not significantly improved at 1 year. However these results are difficult to interpret because the measured angles were small [23].

4.5. Interbody fusion

The rate of Lenke 1 and 2 interbody fusions was 72.6% at 1 year, which might seem low, however this may also be due to a postoperative follow up that was too short to determine definitive successful or unsuccessful fusion.

The rare use of BMP did not influence these results. Although Tsahatsaris et al. [24] reported a very good rate of fusion, this was associated with possible specific complications (radiculitis, osteolysis). These points are emphasized by NASS recommendations, which in 2014 state that the use of BMP for TLIF should be limited to revision surgery as well as osteoporotic patients.

Finally tobacco consumption remains a risk factor of interbody non-union [25] at one year (OR = 2.16, 0.96–4.86).

4.6. Clinical outcome of interbody fusion

No significant difference was found in the functional outcome between patients with/without union at 1 year. These results should be interpreted with caution because the evaluation of interbody fusion by CT scan is still difficult.

These results raise the question of the usefulness of systematic CT scan at the one-year follow-up to determine the presence of solid fusion. We feel that it would be reasonable to limit CT scan at one year to a population of patients with poor clinical results to identify any possible nonunion requiring surgical revision thus reducing medical costs and radiation exposure to patients.

4.7. Limits of this study

Although none of the patients classified as Lenke 3 have required revision surgery for further arthrodesis, longer follow-up of their clinical and radiological outcome is needed. The delay before returning to work, which could not be studied due to various biases, is a pertinent variable that we feel should be studied in future studies.

5. Conclusions and perspectives

The results of this study, which must be confirmed in longer term studies, show that the clinical and radiological goals were achieved one year after surgery. The postoperative benefits of minimally invasive techniques were confirmed including reduced
Disclosure of interest

The authors have not supplied their declaration of conflict of interest.

References