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Review article

Degenerative lumbar spondylolisthesis. Cohort of 670 patients, and proposal of a new classification

O. Gille[a,*], V. Challier[a], H. Parent[b], R. Cavagna[c], A. Poignard[d], A. Faline[e], S. Fuentes[f], O. Ricart[g], E. Ferrero[h], M. Ould Sliman[i], the French Society of Spine Surgery (SFCR)[j]

[a] *Service de chirurgie orthopédique et traumatologique, hôpital Tripode, place Amélie-Raba-Léon, 33076 Bordeaux cedex, France*
[b] *Clinique Saint-Léonard, 18, rue de Bellinière, 49800 Trélazé, France*
[c] *Clinique mutualiste de la Porte-de-L'Orient, 3, rue Robert-de-la-Croix, 56100 Lorient, France*
[d] *Hôpital Henry-Mondor, 51, avenue du Maréchal-de-Lattre-de-Tassigny, 94010 Créteil, France*
[e] *Centre orthopédique Santy, 24, avenue Paul-Santy, 69008 Lyon, France*
[f] *Service de neurochirurgie, hôpital La Timone, 264, rue Saint-Pierre, 13385 Marseille, France*
[g] *Hôpital Kirchberg, 9, rue Edward-Steichen, 2540 Luxembourg-Kirchberg, Luxembourg*
[h] *Service d'orthopédie, hôpital Beaujon, 100, boulevard du Général-Leclerc, 92110 Clichy, France*
[i] *Hôpital Charles-Nicolle, 1, rue de Germont, 76000 Rouen, France*
[j] *94, rue Bobillot, 75013 Paris, France*

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ABSTRACT

Degenerative spondylolisthesis is common in adults. No consensus is available about the analysis or surgical treatment of degenerative spondylolisthesis. In 2013, the French Society for Spine Surgery (Societe francaise de chirurgie du rachis) held a round table discussion to develop a classification system and assess the outcomes of the main surgical treatments. A multicentre study was conducted in nine centres located throughout France and Luxembourg. We established a database on a prospective cohort of 260 patients included between July 2011 and July 2012 and a retrospective cohort of 410 patients included in personal databases between 2009 and 2013. For patients in the prospective cohort clinical assessments were performed before and after surgery using the self-administered functional impact questionnaire AQS, SF12, and Oswestry Disability Index (ODI). Type of treatment and complications were recorded. Antero-posterior and lateral full-length radiographs were used to measure lumbar lordosis (LL), segmental lordosis (SL), pelvic incidence (PI), pelvic tilt (PT), sagittal vertical axis (SVA), and percentage of vertebral slippage. Mean follow-up was 10 months. We started a randomised clinical trial comparing posterior fusion of degenerative spondylolisthesis with versus without an inter-body cage. 60 patients were included, 30 underwent 180° fusion and 30 underwent 360° fusion using an inter-body cage implanted via a transforaminal approach. We evaluated the quality of neural decompression achieved by minimally invasive fusion technique. In a subgroup of 24 patients computed tomography (CT) was performed before and after the procedure and then compared. Mean age was 67 years and 73% of degenerative spondylolisthesis were located at L4-L5 level. The many surgical procedures performed in the prospective cohort were posterior fusion (39%), posterior fusion combined with inter-body fusion (36%), dynamic stabilization (15%), anterior lumbar fusion (8%), and postero-lateral fusion without exogenous material (2%). Peri-operative complications of any severity occurred in 17% of patients. The AQS, ODI and SF12 scores were improved significantly at follow-up. We found no differences in clinical improvements across surgical procedure types. Circumferential fusion (360°) was associated with greater relief of nerve root pain and better lordosis recovery after 1 year compared to postero-lateral fusion (180°). Post-operative CT images showed effective decompression of nervous structures after minimally invasive fusion. Longer follow-up of our patients is needed to assess the stability of the results of the various surgical procedures.

* Corresponding author. Service de chirurgie orthopédique et traumatologique, hôpital Tripode, place Amélie-Raba-Léon, 33076 Bordeaux cedex, France.
E-mail address: olivier.gille@chu-bordeaux.fr (O. Gille).

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Based on a radiological analysis, the authors propose a new classification with five types of degenerative spondylolisthesis: type 1, SL > 5° and LL > PI-10°; type 2, SL < 5° and LL > PI-10°; type 3, LL < PI-10°; type 4, LL < PI-10° and compensated sagittal balance with PT > 25°; and type 5, sagittal imbalance with SVA > 4 cm.
Proof level: IV Observational cohort study. Retrospective review of prospectively collected outcome data.

1. Introduction

Degenerative spondylolisthesis, also known as arthritis spondylolisthesis as opposed to isthmic spondylolisthesis due to pars interarticularis disruption, is encountered on an everyday basis by spine surgeons. Despite this high frequency, the pathophysiology of the vertebral slippage remains controversial, and numerous treatment options are available to the surgeon. The absence of a consensus about degenerative spondylolisthesis prompted the French Society for Spine Surgery (Société française de chirurgie du rachis) to hold a round table discussion in 2013. The main objectives were to characterise degenerative spondylolisthesis, develop a classification system, and assess the outcomes of the various surgical options used by the participating surgeons. Iatrogenic spondylolisthesis, due for instance to excessively aggressive arthrectomy, and spondylolisthesis developed above a fused level are outside the scope of this article, which focuses only on primary degenerative spondylolisthesis.

2. Preparatory work

Several studies were performed to prepare the round table discussion.

2.1. Establishment of a multicentre cohort of patients with degenerative spondylolisthesis

We established a database on a prospective cohort of 260 patients included between July 2011 and July 2012 and a retrospective cohort of 410 patients included in personal databases between 2009 and 2013. Data on the 670 patients were entered into a single Keops database (S.M.A.I.O, Lyon, France). Patients in the prospective cohort were evaluated before and after surgery, using the self-administered functional impact questionnaire AQS [1], the SF12, and the Oswestry Disability Index (ODI). Mean follow-up of this cohort was 10 months. For each patient, antero-posterior and lateral full-length radiographs were digitised and analysed using the radiograph analysis software in Keops.

2.2. Randomised clinical trial of posterior fusion with versus without an inter-body cage

Of 60 patients included at a single centre, 30 underwent single-level fusion using pedicle screws and postero-lateral grafting combined with decompression via recalibration (180° fusion) and 30 also received an inter-body cage implanted via a transforaminal approach (360° fusion). The primary outcome measure was a successful procedure after 24 months defined as healing of the fusion site documented by computed tomography (CT) based on the criteria reported by Lenke et al. [2], less than 5° of fused segment mobility on dynamic views, a greater than 3° increase in fused segment lordosis, and absence of revision surgery. Secondary outcome measures consisted of complications, radiographic parameters (lumbar lordosis [LL] and disc height), clinical parameters (visual analogue scale [VAS], Prolo score [3], ODI, and SF36 quality-of-life scores)

2.3. Evaluation of the quality of decompression achieved by minimally invasive fusion

Transforaminal lumbar inter-body fusion (TLIF) and fusion via a bilateral minimally invasive approach was performed in 24 patients with degenerative spondylolisthesis, who underwent CT before and after the procedure. The height of the foramen on the side opposite the TLIF procedure was measured on both pre and postop CT on a sagittal reconstruction. The surface area of the spinal canal was assessed subjectively, as the arthrectomy would have made this parameter difficult to measure. The morphology of the stenosis was evaluated based on the qualitative classification developed by Schizas et al. [4]. Disc height was measured midway between the anterior and posterior edges of the supra-jacent vertebra.

3. Results

3.1. Multicentre cohort of patients with degenerative spondylolisthesis

Of the 670 patients in the cohort, 260 were included prospectively and 410 retrospectively. Mean age was 67 ± 11 years and 72% of patients were women. The slippage was located at L5-S1 in 6% of cases, L4-L5 in 73%, L3-L4 in 18%, and L2-L3 in 3%; 12% of patients had slippage at two or more levels.

The many surgical procedures performed in the prospective cohort were posterior fusion (39%), posterior fusion combined with inter-body fusion (same-stage TLIF or complementary anterior stage, 36%), dynamic stabilization (15%), anterior lumbar inter-body fusion (ALIF, 8%), and postero-lateral fusion without exogenous material (2%). At least one complication occurred in 16.9% of patients. Major complications included neurological compromise (4.9%), instrumentation-related adverse events (3.6%), and deep surgical-site infections (0.5%). Minor complications were superficial surgical-site infections, dural tears, and systemic complications. No deaths or life-threatening complications were recorded.

3.1.1. Clinical parameters

The global AQS score improved from 36% pre-operatively to 70% post-operatively; the radicular subscore improved from 28 to 72%, the low-back-pain subscore from 31 to 61%, and the neuroischaemic subscore from 48 to 80%. All four improvements were statistically significant ($P < 0.001$). The ODI improved significantly, from 45% pre-operatively to 23% post-operatively ($P < 0.001$). The Physical Component Summary SF12 subscore improved from 32 pre-operatively to 41 post-operatively and the mental component summary SF12 subscore from 39 pre-operatively to 45

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post-operatively ($P < 0.001$). We found no significant differences in clinical improvements across surgical procedure types.

3.1.2. Pre-operative radiological parameters

Mean segmental lordosis, defined as the angle between the tangent to the upper endplate of the slipped vertebra and the tangent to the lower endplate of the infra-jacent vertebra, was 19° at L4-L5 (−48° to +10°) and 16° at L3-L4 (−48° to +10°). Mean slippage was 17% at L4-L5 and 10% at L3-L4. Fewer than 10% of patients had coronal imbalance on the antero-posterior radiograph. Anterior balance was quantified by measuring sagittal C7 tilt as the angle between the central sacral vertical line (CSVL, plumb line through the centre of the sacral plate) and the line connecting the centre of the sacral plate to the centre of the body of C7. Of the 670 patients, 37% were classified as having anterior imbalance defined as more than 7° of sagittal C7 tilt. A tilt value of 7° was taken as the cut-off indicating imbalance. Mean maximal LL, determined based on the vertebrae with the greatest inclinations, was 53° ± 13°; mean PI was 59° ± 11°; and mean PT was 23° ± 8°. In the subgroup with multi-level spondylolisthesis, mean PI was 62°, and mean PT was 26°.

3.2. Randomised clinical trial of posterior fusion with versus without an inter-body cage

Here, we report the preliminary outcomes after a mean follow-up of one year. The rate of peri-operative complications (dural tears, bleeding, and infection) was similar in the two groups (3% in the 180° group and 1.8% in the 360° group). Revision surgery was required in two patients in the 180° group, for infection and extension of the construct after eight months because of persistent sagittal imbalance, respectively. Segmental lordosis was significantly greater in the 360° group (by 3°); however, restoring segmental lordosis was not the main goal of the procedure. The two groups showed no significant differences one year after surgery in any of the clinical scores (Prolo, ODI, and SF36). In contrast, relief from nerve root pain was significantly greater in the 360° group (VAS nerve root pain score, 53 pre-operatively and 9 post-operatively versus 48 and 22 in the 180° group).

3.3. Evaluation of the quality of decompression achieved by minimally invasive fusion

Mean pre-operative slippage was 15% (range, 3–31%). Lumbar spinal stenosis grades according to Schizas et al. [4] were A in two patients, B in seven, C in seven, and D in eight patients. Surgery did not significantly decrease the amount of slippage in this small group of patients. A minimal increase in slippage was recorded in seven (28%) patients. The neural foramen on the side of TLIF was fully patent and the size of the contralateral neural foramen was significantly increased, by 5.7%. Disc height was significantly increased, by 21%. The subjective evaluation indicated widening of the spinal canal.

4. Discussion

4.1. Multicentre cohort of patients with degenerative spondylolisthesis

To our knowledge, this is the largest cohort of patients with degenerative spondylolisthesis reported to date. Our results confirm that PI is increased in degenerative spondylolisthesis. Other findings included decreased LL and increased PT. No significant differences were found across surgical procedures (anterior fusion, posterior fusion, anterior and posterior fusion, dynamic stabilization, and isolated decompression) regarding improvements in measures of quality of life or functional impact. However, the short follow-up of only 10 months on average provides no information on mid- or long-term outcomes. Whether the surgical results are sustained over time will have to be determined by continued follow-up of these patients. The complication rate was similar to that in a meta-analysis by Nasser et al. [5] (17.8% of 79,471 patients). The higher complication rates found by Nasser et al. in prospective studies (20.4% for major and minor complications) are ascribable to better data collection [5].

4.1.1. Dynamic stabilization

In this cohort, 24 patients were managed by the implantation of a dynamic stabilization system secured by pedicle screws. Dynesys® (Zimmer) was used in 21 patients and BDyn® (S14 Implants) in three patients. Revision surgery was required within 18 months in four patients, because of bleeding within the spinal canal, deep surgical-site infection, screw displacement, and anterior imbalance, respectively. An anterior approach to the lumbar spine was used for revision surgery in the patients with screw displacement and anterior imbalance. Outcomes after dynamic stabilization for spondylolisthesis have varied across published studies: Ricart et al. reported good or very good outcomes in 25 patients with a mean follow-up of 34 months [6]; Hoppe et al. obtained satisfactory results, with a 7-year revision rate of 21%, i.e., similar to that seen after fusion according to the authors [7]; and Schnake et al. described the 2-year outcomes as good despite material failure in 17% of patients [8].

4.1.2. Classification of degenerative spondylolisthesis: Before the round table discussion, one of the authors of this study had suggested a new classification system for spondylolisthesis derived from the adult spinal deformity (ASD) classification system developed by Schwab et al. [9]

- type 1: preserved segmental lordosis (> 5°) and preserved LL (LL > PI-10°);
- type 2, decreased segmental lordosis (< 5°) and preserved LL (LL > PI-10°);
- type 3, decreased LL (LL < PI-10°);
- type 4, decreased LL (LL < PI < 10°) with compensation to maintain sagittal balance (PT > 25°);
- type 5, sagittal unbalance (SVA > 4 cm, with the SVA defined as the distance between the plumb line from the centre of the C7 body to the anterior margin of S1 plate) (Fig. 1).

This classification has therapeutic implications according to the authors, as severity increases from each type to the next: preserved segmental lordosis and no other local alterations in type 1, altered segmental lordosis in type 2, altered global LL in type 3, adverse effect on overall balance with compensation in type 4, and altered overall balance in type 5:

- in type 1 spondylolisthesis, there is no need to restore SL, and simple posterior fusion without an inter-body cage therefore seems appropriate. Elderly type 1 patients are probably the best candidates for simple decompression without fusion. Finally, dynamic stabilization may have its best indication in type 1 spondylolisthesis. These hypotheses require validation in larger studies;
- type 2 spondylolisthesis requires SL restoration at the site of slippage. In healthy individuals, L4-S1 lordosis contributes two-thirds of the total LL. An inter-body cage can be extremely useful in this situation, as studies have demonstrated that an anterior support helps to correct local kyphosis and to limit the risk of mechanical post-operative complications;
- in type 3 spondylolisthesis with good correction of the low LL on dynamic views, a short assembly may be appropriate. When LL

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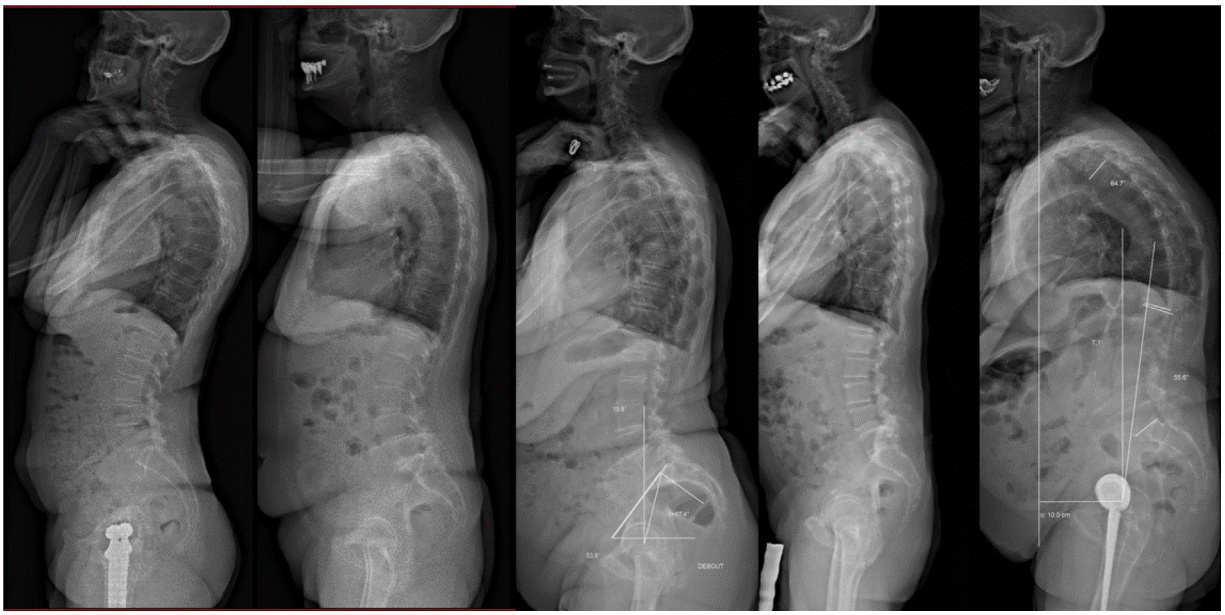

Fig. 1. Different patterns of degenerative spondylolisthesis. Type 1: preserved segmental and global lordosis; type 2: segmental kyphosis; type 3: lumbar hypolordosis; type 4: pelvic retroversion; type 5: sagittal imbalance.

correction is inadequate, the surgical treatment is the same as in type 4 spondylolisthesis;
- in type 4 spondylolisthesis, LL restoration is mandatory and requires an extended construct, often from L3 to S1;
- in type 5 spondylolisthesis, the treatment of the slippage takes second place to correction of the sagittal deformity.

4.2. Usefulness of an inter-body cage

In several studies, outcomes were less favourable after isolated decompression than after fusion in patients with degenerative spondylolisthesis [10–12]. The clinical outcome depends on the quality of the fusion [13]. Although fusion can be achieved without internal fixation (by postero-lateral grafting), there is abundant evidence that internal fixation increases the healing rate [14]. Similarly, circumferential fusion may increase the healing rate in all types of lumbar surgery [15,16]. No published studies compared postero-lateral fusion to circumferential fusion in patients with degenerative spondylolisthesis. The preliminary results of our randomised trial comparing 180° fusion and 360° fusion do not support the routine use of an inter-body cage. An inter-body cage is undoubtedly useful in patients requiring local lordosis restoration (type 2 spondylolisthesis). The implantation of a cage that can serve as an anterior pivot point can help to restore segmental lordosis. Some authors have suggested that inter-body cage implantation may also be preferable in patients with high discs, to minimise the risk of failed fusion [15,16].

4.3. Neurological decompression

4.3.1. Isolated neurological decompression without fusion

This technique has acquired a poor reputation, as increased slippage has been reported after decompression laminectomy without fusion used to treat degenerative spondylolisthesis. In 1991, Herkowitz and Kurz reported that fusion provided better outcomes than did isolated decompression [10]. However, the introduction of micro-surgical techniques has challenged this paradigm. Isolated microsurgical unilateral decompression has produced good clinical and radiographic outcomes with no significant increase in slippage [17]. In other studies, however, microsurgical unilateral decompression was associated with a subsequent increase in slippage [18,19]. Jang et al. reported that the risk of increased slippage was greatest in patients whose pre-operative dynamic radiographs showed sagittal motion at the spondylolisthesis level [18].

4.3.2. Neurological decompression with fusion

Neurogenic claudication requires cauda equina decompression to alleviate the symptoms. Decompression can be achieved directly via laminectomy or recalibration. However, these techniques carry a risk of dural tearing that may be greatest when degenerative spondylolisthesis is combined with lumbar spinal stenosis [20]. Decompression can also be achieved indirectly by reducing the slippage or distracting the inter-vertebral space [21,22]. Surgery via an isolated anterior approach has been reported to provide good nervous structure decompression and favourable clinical outcomes. In a study by Hirose comparing pre-operative and post-operative myelograms, spinal canal dimensions increased in 80% of patients after anterior surgery and clinical manifestations improved in 60% [23]. Luczkiewicz et al. obtained similar findings [24]. In the prospective cohort established by the French Society for Spine Surgery, 20 patients were treated via an isolated anterior approach. They experienced significant improvements in nerve root pain (VAS score, 7.7 pre-operatively and 2 post-operatively) and a decrease in slippage (L5-S1, from 18% pre-operatively to 10% post-operatively; and L4-L5, from 17% pre-operatively to 11% post-operatively). Revision surgery via a posterior approach was required in one (5%) patient to treat worsening of the neurological manifestations. Fusion was considered complete after one year in all 20 patients. It should be borne in mind, however, that the anterior approach increases the lumbar lordosis and consequently can worsen the static component of lumbar spinal stenosis. To minimise this risk, inter-vertebral distraction should be used also. The patient must be informed that posterior revision surgery for secondary release may be required.

In our randomised trial comparing 180° and 360° fusion, the degree of relief from nerve root pain reported after one year was greater with the inter-body cage technique. The cage was implanted via the transforaminal approach in all patients. The cage was implanted on the side of most severe pain. The greater efficacy

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on nerve root pain may be ascribable to optimal neural foramen decompression by the passage of the cage.

Minimally invasive fusion techniques allow adequate decompression, as demonstrated in the study involving post-operative CT. Decompression can also be achieved in patients with severe stenosis (stage D in the Schizas classification) [4]. Kelleher et al. also established that minimally invasive fusion was effective in the treatment of degenerative spondylolisthesis, although increased slippage was noted in 8.4% of patients [25].

5. Conclusion

This article reports the results of a round table discussion held in 2013 by the French Society for Spine Surgery. The participants initiated a prospective longitudinal study of a large cohort of patients with degenerative spondylolisthesis. The clinical follow-up is still very short and must be continued to collect mid-term and long-term data, which are crucial to assess the various surgical techniques used in this multi-centre study. The radiographic analysis of overall postural balance will be discussed in another article. Finally, the definite results of the randomised trial comparing instrumented postero-lateral fusion to circumferential fusion will be available shortly, as this trial will be completed in one year.

Disclosure of interest

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

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