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Remodelling of the sacrum in high-grade spondylolisthesis: a report of two cases

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Abstract Two young patients are described, who were operated on for high-grade spondylolisthesis. A good posterolateral fusion was achieved, without decompression and without reduction. The clinical course was favourable, the tight hamstring syndrome resolved. Disappearance of the posterior-superior part of the sacrum and of the posterior part of the L5-S1 disc was observed on comparing pre- and postoperative magnetic resonance (MR) images. This resulted in normalisation of the width of the spinal canal. Around the

L5 nerve roots in the L5-S1 foramina some fat reappeared. These anatomical changes on MRI could play a role in the disappearance of clinical symptoms.

Keywords Spondylolisthesis · Spinal fusion · Sacrum · Hamstring contracture

Introduction

Wiltse et al. [41] proposed a classification of spondylolysis and spondylolisthesis, the different forms being defined as: dysplastic, isthmic, degenerative, traumatic and pathological spondylolisthesis. Most high-grade spondylolisthesis patients have an isthmic form, but often with dysplastic phenomena such as a bifid arch or subluxation of the facet joints.

The treatment of high-grade spondylolisthesis (slip percentage of more than 50%, Meyerding grade 3, 4 or 5) is highly controversial. This condition is relatively rarely seen, and large series comparing non-operative and operative treatment or different operative treatments are not available. Although Weinstein mentions, in a review article [40], that 11 non-operated patients with a high-grade spondylolisthesis led an active life with only minor adjustments 18 years after the original diagnosis, most patients and orthopaedic surgeons favour an operative treatment [21]. In the same review article, 21 patients treated by fusion in situ had even fewer symptoms than the untreated group. The degree of slip did not influence the re-

sults. However, several other authors mention dissatisfaction among patients after a fusion in situ for high-grade spondylolisthesis [6, 17]. Even neurologic complications are described after fusion in situ [23, 32], but they are more frequent after reduction manoeuvres [1, 5, 6, 14, 24, 26]. The literature seems convincing on the fact that fusion in situ is a good and relatively safe option for patients with significant complaints due to a high-grade spondylolisthesis [13, 15, 16, 29, 33, 34]. This in fact is rather surprising, since the original deformity is not dealt with. MRI observations in two patients lead us to believe that remodelling of the upper sacrum and the lumbo-sacral junction could play a role in achieving these good results.

Case reports

Case 1

A 12-year-old girl was first seen with fatigue in the lumbar region of 1 year's duration. She experienced pain in her legs, which disappeared after she stopped jazz ballet and ballroom dancing. Forward bending was severely restricted, to 20°, and straight leg raising was only possible to 45° bilaterally. The strength of the m. ex-

Fig. 1 Case 1. Preoperative midsagittal T2-weighted magnetic resonance (MR) image shows bisected L5-S1 disc and almost straight posterior border of the sacrum

Fig. 2 Case 1. Preoperative sagittal T1-weighted MR image through the left foramina with compression of the L5 nerve root in the L5-S1 foramen. The posterolateral part of the L5-S1 disc is visible (compare with Fig. 4)

Fig. 3 Case 1. Midsagittal T2-weighted MR image obtained at 42-months follow-up. Anterior bowing of the posterior cortex of S1 with increase in the S1-S2 angle, suggestive of remodelling of the posterior-superior corner of the S1 vertebra, can be seen. Disappearance of the posterior part of the disc L5-S1 is also evident

tensor hallucis was diminished bilaterally. The step at L5 was painful on palpation. Radiographs showed an isthmic spondylolisthesis of L5-S1 with an elongated arch of L5. The upper endplate of S1 was severely dysplastic, with severe rounding of the contour. The slip percentage was 59%, measured with the modified Taillard technique [37] and the slip angle was 39° kyphosis. The pelvic incidence angle was 78°. MRI examination showed bilateral compression of the L5 nerve roots in the L5-S1 foramen, without mid-line compression of the dural sac (Fig. 1, Fig. 2). A posterolateral fusion of L5-S1 in situ (instead of L4-S1, to minimise the loss of motion) was opted for, with an attempt to correct the slip angle with a spica cast with leg extension in hyperextension. This reduced the slip percentage to 43% and the slip angle to 24° kyphosis. After 3 months of recumbency, a good fusion was observed, but the correction obtained in the spica cast was lost, returning to the preoperative values. At 42 months postoperatively the patient had no pain, but occasionally suffered fatigue in the lower back and legs. Physical examination showed an unrestricted function of the lumbar spine with straight leg raising of 70°. The strength of the extensor hallucis was normal. The radiographs showed a good posterolateral fusion L5-S1, enlargement of the anterior part of S1 with more buttress toward the L5 vertebra, and some resorption of the posterior border of S1. The angle between the posterior borders of S1 and S2 had increased from 10° preoperatively to 15°. The slip percentage was 41%, diminished compared to the preoperative value, due to the resorption of the posterior part of S1. The slip angle had also diminished, to 19° kyphosis. The pelvic incidence an-

Fig. 4 Case 1. Postoperative sagittal T1-weighted MR image through the left foramina, showing reappearance of the L5 nerve root surrounded by normal fat in the L5-S1 foramen. Resorption of the posterolateral part of the L5-S1 disc is evident

gle had increased to 84° . The remodelling of the sacrum is best appreciated on MR images: the posterior half of the L5-S1 disc had disappeared and the posterior cortex of the S1 vertebra was more curved anteriorly. The posterior cortex of S1 was almost continuous with the posterior cortex of L5; preoperatively the AP distance between these two cortices had been substantial. The widening of the posterior aspect of the S1-S2 disc remnant, as described by Antoniadou et al. [2], was unchanged. The reappearance of fat in the foramen L5-S1 around the L5 nerve root was evident (Fig. 3, Fig. 4).

Case 2

A 16-year-old boy was first seen with complaints of the low back while playing tennis and undertaking other strenuous activities, which dated back 1.5 years. He also reported minimal pain in the posterior side of the upper legs. Physical examination revealed a short torso with a deepened lumbar lordosis. Forward bending was severely restricted, to 25° , and somewhat painful. Straight leg raising was possible to 40° bilaterally. There were no neurologic abnormalities. Radiographs showed a severe spondylolisthesis of L5-S1 with dysplastic components on the anteroposterior view (Fig. 5). The pars interarticularis on the right side was elongated without an obvious isthmic defect. The pars interarticularis on the left side seemed incompletely separated. The percentage slip was 94% and the slip angle was 52° of kyphosis. The pelvic incidence angle was 82° . MRI investigation showed a severely narrowed dural sac at the posterior ridge of S1. The L5-S1 disc was bisected (Fig. 6). The nerve root L5 was squeezed in the flattened L5-S1 foramen. At operation the upper sacrum showed a spina bifida. The arch of L5 was severely dysplastic, the L5-S1 facet joint was hypertrophic at the right side and hypoplastic at the left side. At the right side a spondylolysis was present, at the left side the arch was almost absent. A posterolateral fusion of L4-S1 was performed with iliac crest bone, supplemented with allogenic bone bank bone. Cerclage wires were inserted through the base of the L2, L3 and L4 spinous processes. The spondylolisthesis appeared to be very little reducible during operation, while applying traction on the inserted cerclage wires. After 7 days the patient received a spica cast with unilateral leg extension and traction wires were mounted on a traction frame, incorporated in the cast. Our modified traction method (without external fixation pins or a halo-pelvic apparatus) has been described by Balderston and Bradford [3], Ohki et al. [28] and Snijder et al.

Fig. 5 Case 2. Preoperative anteroposterior (AP) radiograph showing dysplastic and incomplete arch of L5. Five lumbar laminae and only three lumbar vertebral bodies are fully visible

[36]. In traction, the slip percentage was reduced to 58% and the slip angle corrected to 13° of kyphosis. Unfortunately, the traction wires cut through the spinous processes and the reduction was partially lost at 1 month postoperatively. After removal of the traction wires and another 2 months' recumbency in plaster, the fusion looked solid. The boy was mobilised, wearing a spica cast with leg extension for 6 more weeks. The correction was further lost to the preoperative values. He was seen regularly, and had no complaints whatsoever. He had an unrestricted forward bending, and straight leg raising was possible to 90° . X-ray investigation showed a strong fusion posterolaterally (Fig. 7). The anterior side of L5-S1 fused spontaneously and the posterior cortex of S1 became more anteriorly curved. The angle between the posterior cortices of S1 and S2 increased from 12° preoperatively to 51° at last follow-up, almost 7 years after operation. The slip percentage was 59% and the slip angle was 36° kyphosis, both substantially decreased due to the remodelling process of S1. The pelvic incidence has increased to 115° , as a consequence of the increased slope of the remodelled S1 endplate. On MRI examination a substantial remodelling and

Fig. 6 Case 2. Preoperative midsagittal T1-weighted MR image, showing pronounced narrowing of the spinal canal at L5-S1. The posterior part of the L5-S1 disc is visible on top of S1

resorption of the posterior part of the S1 vertebra with widening of the spinal canal was noted. The posterior part of the L5-S1 disc had been totally resorbed (Fig. 8). Also, fat had reappeared in the L5-S1 foramina. The posterior widening of the S1-S2 disc remnant was unchanged on comparison between the two MRI studies.

Discussion

Remodelling phenomena of the spine are well known. After a posterior or posterolateral fusion in young children the disc at the same level becomes progressively narrow and sometimes fuses spontaneously. Furthermore, in cases of spondylolisthesis, the S1 vertebra can enlarge on the anterior side and show the phenomenon of buttressing. This can develop after a fusion procedure or spontaneously [37].

We observed two patients with high-grade spondylolisthesis, who were treated operatively, in whom remodelling of the sacrum is obvious on comparing preoperative and postoperative MRI scans. In these patients the postoperative correction of slip percentage and slip angle was lost, but a good posterolateral fusion occurred. Over the course of years, the posterior part of the L5-S1 disc resorbed and the posterosuperior part of S1 bent anteriorly and became more rounded. This process can be monitored by measuring the angle between the posterior borders of S1 and S2. This angle can be measured on plain radiographs as well as on MRI scans, provided that the sacrum is well visualised. In the first patient, this angle changed from $+10^\circ$ to $+15^\circ$ in 42 months, which is only modest. In the second patient, however, this angle changed from $+12^\circ$ to $+51^\circ$ after 83 months. This change in the S1-S2 angle over time and the visible differences between the shape of the sagittal profile of the sacrum pre- and postoperatively must be the result of remodelling and resorption of bone.

Fig. 7 Case 2. AP radiograph of the lumbar spine obtained 6 years postoperatively shows a mature fusion mass of L4-S1 posterolaterally

During this process the spinal canal at the lumbo-sacral junction spontaneously enlarges.

In the important work of Vidal and Marnay [39], this change of the shape of the upper sacrum in some patients is described, occurring over a period of years in the growth period. The S1-S2 angle is one of the parameters of this change of shape. They describe this bowing of the sacrum as a kyphosis, giving the verticalised sacrum a more horizontal appearance. The remodelling is considered to take place under the influence of biomechanical forces, described as the hinged couple around the hip joints. No mention is

Fig. 8 Case 2. Midsagittal T1-weighted MR image almost 7 years postoperatively. Reconstitution of the spinal canal at L5-S1 by remodelling of the upper sacrum with resorption of the posterior part of the L5-S1 disc is evident

made of remodelling of the spinal canal nor of any relationship with tight hamstring syndrome.

In a recent article by Antoniadou et al. [2], wide variations in the sagittal shape of the sacrum were found in 45 patients with non-operated, non-degenerative spondylolisthesis. The role of remodelling of the sacrum in the process of reaching the final configuration was not discussed, but considerable changes in shape of the sacrum must have occurred to reach the more abnormal, often bowed or kyphotic, sagittal profiles described by the authors.

Marty et al. [22] describe a more curved sacrum in their 39 isthmic spondylolisthesis patients, and a close relationship between the sagittal shape of the sacrum and the pelvic incidence angle was found. The pelvic incidence angle was considerably larger in the spondylolisthesis group (mean 64°) compared with the normal population (mean 51°). In our two described patients, the pelvic incidence angles were considerably greater, possibly indicating the severity of the spondylolisthesis and the changes in the contour of the upper sacrum. Marty et al. postulate that a greater incidence leads to a greater sacral slope, and this could be one of the predisposing factors for the slipping. In our view however, an increase in the pelvic incidence could be the result of the slipping. The remodelling process changes the inclination of the upper sacral endplate (increasing the sacral slope), which results in the line perpendicular to the endplate shifting more towards the horizontal, thereby giving rise to an increase in the incidence. This increase in the pelvic incidence angle was, in fact, seen in our two patients. Marty et al. do not mention that the more rounded sagittal shape of the sacrum could be the result of remodelling of the sacral bone. Their S2 inferior angle, resembling our S1-S2 angle, was signifi-

cantly smaller in normal adults (12.9°) compared with the spondylolisthesis group (17.6°). This can be viewed as more bowing of the upper sacrum.

Boxall and Bradford and colleagues [4] define remodelling of the lumbo-sacral junction as a decrease in percentage of slipping of 10% or more, or a decrease in the slip angle of 10° or more. It is obvious that the slip percentage decreases as the posterior part of S1 resorbs and that the slip angle decreases as the posterior cortex of S1 bows more anteriorly. They note a significant change in the relationship of L5 to S1 in five patients with a fusion at a young age, but these changes are not fully described. They presume that the remodelling and decrease in slip percentage and angle are secondary to a change in the weight-bearing stresses at the level of the slipping.

High-grade dysplastic spondylolisthesis remains an intriguing and difficult problem for both the patient and the orthopaedic surgeon [4, 10, 21, 27, 40]. Not only is the cosmetic deformity an issue, but pain, restriction of function and sometimes neurologic deficit as a result of compression of the dural sac and nerve roots can also be present. Posterolateral fusion in situ with or without decompression gives consistently good results, but neurologic deficit postoperatively has been described [23, 32]. Concern is also raised about progression of the slip in case of pseudarthrosis or with bending of the fusion mass.

A variety of techniques has been described in the literature to reduce the slipped L5 vertebra upon S1 [1, 5, 7, 12, 14, 20, 26, 31]. These repositioning manoeuvres pose a risk to the L5 nerve root [30], and postoperative deficit, whether temporary or definitive, is mentioned in almost all larger series [1, 5, 6, 14, 24, 26]. Paresis of proximal lumbar roots is also described [38]. Even with the Gaines technique, in which the L5 vertebra is resected from anterior and posterior, and the L4 vertebra is located on top of S1, neurologic deficits have been described [12, 20].

In all these articles, whether dealing with fusion in situ or with reduction of the slipped vertebra, remodelling of the lumbosacral junction has never been described. Our findings support the choice of a fusion in situ or a fusion with limited reduction of the slip, since the remodelling process of the sacrum is believed to be an important phenomenon in the gradual disappearance of preoperative complaints.

The process of remodelling of the posterior upper sacrum resembles the spontaneous clearance of the spinal canal in burst fractures, in which some resorption of the retropulsed vertebral body fragment takes place over time [8, 9, 11, 18, 19, 25, 35]. The dural sac, with its constant pulsating pressure on the narrowed bony walls of the spinal canal, may induce this bone resorption, which may explain this dynamic process. It is presumed that younger patients have more potential for remodelling. Stabilization of the lumbo-sacral spine, whether spontaneous in the evolution of an important spondylolisthesis or after fusion, seems important for allowing the sacrum to remodel.

Whether the dural sac pressure or the biomechanical forces (or both) induces the remodelling process, is speculative.

It is a clinical phenomenon that, after obtaining a good fusion, the tight hamstrings, if present, disappear and straight leg raising and forward flexion of the spine becomes progressively possible. In the light of our observations on these two patients, we think that the substantial remodelling of the upper sacrum and spontaneous widening of the spinal canal could play an important role in the disappearance of the preoperative complaints. The compression of the L5 nerve root in the L5-S1 foramen can also disappear, as is shown in both patients.

The authors strongly believe that the potential for bone remodelling at the lumbo-sacral junction and concurrent spontaneous widening of the spinal canal in young spondylolisthesis patients is remarkable and should be a subject of further study.

Conclusion

In the treatment of high-grade spondylolisthesis in children and young adults, the potential of remodelling of the upper sacrum and the lumbo-sacral junction should be considered, provided that there is a stable situation. A hitherto incompletely described element of the remodelling process consists of resorption of the posterior part of the S1 vertebral body with widening of the pre-existent narrowed spinal canal. Spontaneous enlargement of the anterior endplate of S1 with buttressing of the L5 vertebra is a well-known phenomenon and occasionally the L5-S1 disc shows spontaneous fusion. This remodelling process may play a role in the disappearance of clinical symptoms, such as the tight hamstrings. Larger series, documented with MRI examinations, need to be evaluated to better understand this process.

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