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A square to indicate the unstable zone in severe spondylolisthesis

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Abstract The reduction and stabilisation of high-grade dysplastic developmental spondylolisthesis by means of modern internal fixators can correct slip, but can leave the sagittal alignment unbalanced, causing instability, e.g. in the adjacent, non-fused lumbar segments. Through analysis of the modifications of imbalance in the spine and pelvic ring due to surgical correction, this study defines the unstable zone of high-

grade dysplastic developmental spondylolisthesis and proposes a simple radiographic method to identify it.

Keywords Spondylolisthesis · Lumbar spine instability · Lumbar fusion

Introduction

This study demonstrates a simple method of using standing radiographs to determine the unstable zone in severe spondylolisthesis and indicates the area of fusion when reduction is performed. Following the Marchetti–Bartolozzi classification [7], the spondylolisthesis considered is the high-grade dysplastic developmental type, while the Wiltse classification considers it as being the congenital type I A [11].

In 1983, Vidal and Marnay [10] published a study on the morphology and sagittal body balance of high-grade dysplastic developmental spondylolisthesis. These authors studied the global sagittal alignment of the spine in patients with spondylolisthesis and stated that there are four fundamental factors in this pathology:

1. Slip
2. Pelvic retroversion
3. Verticalisation of the sacrum
4. Forward displacement of the hips

These four factors cause the loss of normal alignment along the line from the external auditory meatus, lumbar sacral joint and centre of femoral head and determine the course of each case and its treatment. Vidal and Marnay

measured the pelvic retroversion and forward displacement of the hips and their influence on the appearance of slipping.

The best-known, non-surgical reduction technique is Scaglietti's plaster cast [8], which also includes the thigh and can reduce the slip, pelvic retroversion, verticalisation of the sacrum and forward displacement of the hips. Unfortunately, it is extremely uncomfortable for the patient and is therefore rarely used today [4]. The introduction of new rigid pedicular instrumentation with a fixed angle between the screw and vertical bar further improved the opportunity of reducing and stabilising high-grade spondylolisthesis by occasionally using only a posterior approach [3, 5, 6, 9]. Despite these powerful spinal fixations, the difficulty of achieving solid fusion under these particular conditions persists, and the necessity of associating the posterior instrumentation with an interbody fusion has been demonstrated [2]. However, achieving and maintaining reduction of the slip by means of internal fixators, even by adding an interbody fusion, can be difficult, especially when dealing with pelvic retroversion, verticalisation of the sacrum and forward displacement of the hips. In this case, the unstable zone of severe spondylolisthesis should be identified and stabilised.

Fig. 1 Treatment of a 13-year-old girl (*top*). L4 became unstable after 4 months (*right*). Treatment 24-year-old woman (*bottom*)

Materials and methods

From 1978 to 1998, 488 cases of spondylolisthesis were treated surgically at our institution. This study focuses on the retrospective analysis of the 39 high-grade dysplastic developmental spondylolistheses with slip of more than 45%, of which 19 were reduced and 20 fused in situ. The following two cases are indicative of the aim of this study and are described in detail.

A 13-year-old girl (Fig. 1) suffering from high-grade dysplastic developmental L5 spondylolisthesis with 50% slip and severe back

and leg pain was operated on in a two-stage procedure with a posterior and anterior approach. The loose arch of L5 was removed, and the roots of L5 and S1 were identified and decompressed, thus allowing visualisation of the roots during reduction in order to avoid any traction of the roots. Reduction was obtained by means of an AO-USS internal fixator, using two special, double-threaded Schanz screws inserted into the L5 pedicles and two standard Schanz screws inserted into the S1 pedicles. Complete reduction of slip was obtained gradually, by pulling back the L5 vertebra and creating a lordosis of the original kyphotic deformity at L5–S1. Since the disc was very low, no posterior cages were inserted and

Fig. 2 The 13-year-old girl (see Fig. 1) was operated on again; this time, L4 was included in the fusion area. The 2-year follow-up showed a stable correction and a solid fusion mass

the posterior procedure was concluded by an L5–S1 lateral fusion. One week later, anterior L5–S1 interbody fusion was performed and stabilised using a cancellous screw with a washer.

A 24-year-old woman (Fig. 1) suffering from severe back and leg pain caused by high-grade dysplastic developmental L5 spondylolisthesis with 65% slip was treated in a one-stage posterior procedure. Decompression and reduction were performed as in the 13-year-old girl, and since the disc was high enough, a posterolateral interbody fusion (PLIF) with cages was carried out; lateral fusion was added.

Both patients walked without a brace or cast after surgery.

Results

At follow-up after 4 months, the X-rays of the 13-year-old girl showed severe instability of the segment L4/5, and solid fusion of L5–S1 was obvious (Fig. 1). Due to persistent pain, the patient was operated on again using a posterior approach, and L4 was stabilised and fused (Fig. 2). On re-examining the pre-surgery papers of the first operation (including oblique and maximum flexion and extension X-rays), it was confirmed that there were no signs of L4 spondylolysis or of potential L4/5 instability.

In the 24-year-old woman, there was no pain and no loss of correction or stability at follow-up after 4 months, and a solid fusion of L5–S1 was evident.

At follow-up after 2 years, both patients were free of pain and had no loss of correction or stability; solid fusions were obvious in both cases.

Discussion

Vidal and Marnay studied the sagittal alignment in normal subjects and in patients with spondylolisthesis. In the former, the plumbline from the external auditory meatus crosses L5–S1 and passes through the centre of the femoral head; however, in some cases, this alignment can be lost at the L5–S1 level because of a slight forward displacement of the hips, and in this case a small torque (two opposing forces which produce rotation) is formed. In patients with severe spondylolisthesis, the alignment is always lost and the torque is much greater. Vidal and Marnay (Fig. 3) defined this torque (*couple charnière*) as being composed of the body weight (whose force application point is on L5–S1) and of the ground reaction transmitted through the hips (whole force application point is at the centre of the femoral head). They calculated that the percentage between the horizontal segment running from the centre of S2 to the point of intersection with the vertical alignment coming from the external auditory meatus, and the segment running from the centre of S2 to the intersection with the vertical starting from the centre of the femoral head, is more than 80% in a normal subject. In spondylolisthesis, the more slip, pelvic retroversion, verticalisation of the sacrum and forward displacement of the hips there are, the lower this value becomes. Pelvic retroversion is both the cause and effect of the forward position of the hips.

The application of Vidal and Marnay's principle of "couple charnière" (C), allows us to understand the different course of these two apparently similar forms of

Fig. 3 Normal alignment of the body (left). The drawing (centre) and the X-ray (right) illustrate how the C value (*couple charnière*) is calculated. D1 is the horizontal segment running from the centre of S2 to the point of intersection with the vertical alignment running from the external auditory meatus and passing through the L5–S1 disc. D2 is the horizontal segment running from the centre of S2 to the intersection with the vertical alignment starting from the centre of the femoral head

Table 1 Patient details

Patient	Slip (%)	Slip angle	Sacral inclination	Lumbar lordosis	Lumbar index	Risser sign
13-year-old	50	22°	39°	57°	83%	0
24-year-old	65	10°	62°	68°	65%	5

Fig. 4 Course of the “couple charnière” in the 13-year-old girl (*top*) and the 24-year-old woman (*bottom*)

spondylolistheses basically treated in the same way. In fact, although the slip percentage, slip angle, sacral inclination and lumbar lordosis (Table 1) make the two forms of spondylolisthesis similar, the forward displacement of the hips makes them completely different. The pre-operative *C* value (Fig. 4) of the girl's spondylolisthesis was 36% versus the woman's 67%, whereas the normal *C* value given by Vidal and Marnay was more than 80%. In the post-operative X-rays, since L5 was fused to S1, we can calculate the *C* value in L4/5, as this represents the new lumbar-sacral joint; the *C* value was 56% in the girl versus 83% in the woman. This may explain the loss of L4 stability in the girl, since the complete reduction of L5 over the sacrum, which had been left vertical, and the forward displacement of the hips made L4 unstable. The inclusion of L4 in the fusion area brought the *C* value (76%) close to normal.

Farcy and Schwab [5] recently proposed a sagittal pelvic tilt index (SPTI). This index is a technique to quantify the degree of sagittal pelvic plane rotation in a standing patient. The radiographic measurement is the same as Vidal and Marnay's *couple charnière*. In a normal subject, the sagittal alignment of L5 with respect to S2 and the hip joints is included in a range of values (average SPTI, 0.7). Low SPTI caused by pelvic retroversion is related to

kyphotic decompensation syndrome (KDS). Farcy and Schwab defined KDS as the result of decompensation after spinal surgery mainly for degenerative pathology and involving short fusions restricted to the lumbar sacrum region. Instability of the disc above the previous fusion was found and stabilised in patients with KDS. The instability of the L4/5 segment in the 13-year-old girl can be interpreted as junctional instability in the disc above the previous fusion due to KDS (L5-sacrum vertical and flat).

Conclusion

Examination of the above two cases shows us that when the *C* value is low, only the simultaneous reduction of the slip, the sacrum verticalisation and the forward displacement of the hips caused by pelvic retroversion can bring about a stable correction with good balance of the lumbar-sacral junction. This may be possible only by using the technique of pre-operative reduction in Scaglietti's cast or the external fixator technique [1]. In contrast, it would be necessary to know the unstable area of severe spondylolisthesis if an intra-operative reduction were carried out by means of an internal fixator and if L5 were placed over the vertical sacrum and the forward displace-

Fig. 5 The square on the 13-year-old girl, including L4 and L5 (*left*). The square on the 24-year-old woman, including only L5 (*right*)

ment of the hips remained. The unstable zone of high-grade dysplastic developmental L5 spondylolisthesis can be defined by caudal lumbar vertebrae, often only L5, which rest on a sloping disc and are pushed forward and down both by the body weight and also by the pelvic retroversion, which verticalises the sacrum and pushes the hips forward. Although L5 is evidently the pathological vertebra, it can be seen that the pelvic ring (pelvic retroversion) and the lumbar spine (increase of lordosis) are also involved in this type of spondylolisthesis. These caudal lumbar vertebrae included in the unstable zone, even in the absence of spondylolysis, can be involved in slip if, after complete reduction, L5 is fused to the vertical sacrum. In this situation, the combined forces of body weight and pelvic retroversion can make these vertebrae

unstable. This unstable zone can be identified on a standing lateral X-ray which includes the femoral head (Fig. 5). It is possible to draw a square on the X-ray, the sides of which are made up of a segment on the horizontal line through S2. The limits of this segment are given by the intersection with the vertical line running from the halfway point of the L5 caudal plate and another vertical line running from the centre of the femoral head. The vertebrae included in this square have to be fused when L5 reduction is performed, but the sacrum stays vertical and the forward displacement of the hips remains. If L5 reduction is performed together with the correction of both the pelvic retroversion and the hyperlordosis, only L5 needs to be fused.

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