Spondylolysis and isthmic spondylolisthesis: impact of vertebral hypoplasia on the use of the Meyerding classification

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Background: Spondylolysis and isthmic spondylolisthesis are common multifactorial disorders. The extent of slipping of the spondylolytic vertebra is considered a major predictor for prognosis and further follow-up. Vertebral hypoplasia is a common finding associated with spondylolysis. The purpose of this study is to evaluate the incidence of hypoplastic vertebral bodies in patients with spondylolysis and in the general population and to analyse the impact of the findings on the measurement and grading of spondylolisthesis.

Methods: 140 patients with 141 levels of spondylolysis identified by MRI were included in this study. The slippage of the spondylolytic vertebral body and the size in the midline sagittal image were measured and correlated. In addition, a randomised control group was evaluated to test the hypothesis that shortened, hypoplastic vertebral bodies can also be found in the general population.

Results: Shortened, hypoplastic vertebrae were found in 50 patients with spondylolysis and none was found in the control group. These shortened vertebrae mimicked spondylolisthesis and in 19 patients the slippage equalled the shortening, thus mimicking spondylolisthesis, although only spondylolysis was present.

Conclusion: Sagittal shortening of the spondylolytic vertebra is common and may mimic spondylolisthesis. In order to define and measure spondylolisthesis the shortening of the spondylolytic vertebra has to be taken into account.

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Spondylolysis is defined as a defect in the pars interarticularis, whereas spondylolisthesis means slipping of a vertebra in relation to an adjacent vertebra. Spondylolisthesis can occur as a complication of spondylolysis due to a loss of posterior stabilisation in the affected segment. It is then referred to as isthmic spondylolisthesis and should not be confused with other forms of spondylolisthesis, such as degenerative spondylolisthesis [1–2].

The measurement of spondylolisthesis is based on the widely recognised method proposed by Meyerding [3]. Meyerding defined the slippage on plain X-ray imaging in accordance to the vertebra below. The caudal vertebra is divided into four parts. Grade I means a translation of the cranial vertebra of up to 25%, Grade II of up to 50%, Grade III of up to 75%, and Grade IV up to 100%. Grade V was added later, describing the ptosis of the cranial vertebra [3, 4]. Other classifications also exist; however, the measurement of the slip remains the same when using other classifications.

The common diagnostic work-up consists of conventional X-ray imaging in the lateral, anteroposterior and oblique position. MRI or CT is not always performed; however, the hallmarks of spondylolysis and spondylolisthesis on cross-sectional imaging are known. MRI is

considered to be a reliable tool for diagnosing spondylolysis and spondylolisthesis. The spondylolytic defect can almost always be identified on MRI. The characteristic feature of isthmic spondylolisthesis is thought to be a wide spinal canal, often associated with a wedging of the cranial vertebra [5, 6]. Frank et al [7] reported that hypoplasia of the spondylolytic vertebra is common on conventional X-ray imaging and could mimic spondylolisthesis. A recent MRI study has confirmed that finding for cross-sectional imaging [8].

The measurement and the grading of spondylolisthesis are important since the diagnostic work-up and the follow-up depends on the clinical symptoms, the presence or absence of spondylolisthesis and the grade of spondylolisthesis. Spondylolysis is a disorder that does not require an imaging follow-up, whereas spondylolisthesis is usually followed up clinically and with X-ray imaging [9].

We present a MRI study of the largest yet reported number of patients with spondylolysis, which emphasises the role of cross-sectional imaging in the diagnosis and grading of spondylolisthesis. The study shows that hypoplasia has an impact on the Meyerding classification and it questions the inadvertent use of the Meyerding classification without taking into account vertebral hypoplasia for graduating a slip on MRI. We propose a way to measure the vertebral slip and vertebral hypoplasia and to correctly grade these patients.

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Figure 1. Measurement of slippage of the spondylolytic vertebra L5 over S1 is shown in a sagittal midline T_2 weighted scan of the lumbar spine. A similar section is shown with and without the measurements. First line, A, is drawn, which connects the dorsal edges of L5 to each other. Then the upper margin of S1 is pointed to the computer, which draws a parallel line to the first line, B. The connecting line, C, is equal to the slip. The value of this line is recorded in millimetres. L, lumbar; S, sacral.

Materials and methods

2008 MRI scans of the lumbar spine acquired for various reasons between March 2006 and May 2009 at our facility were reviewed retrospectively. 140 patients with spondylolysis or isthmic spondylolisthesis were identified and included in the study. All other patients were excluded from the study group.

Using the Fonar Upright® Multi-Position™ MRI (Fonar, Melville, NY) the following MRI sequences of the lumbar spine were acquired in the sitting position using a two-channel surface coil: sagittal T_2 weighted scan [echo time (TE), 140 ms; repetition time (TR), 1445 ms; matrix, 256×256 or 320×320 ; field of view, 36×36 cm], sagittal T_1 weighted sequence (TE, 15 ms; TR, 420 ms; matrix, 320×320 ; field of view, 36×36 cm), axial T_2 weighted sequence (TE, 120 ms; TR, 1245 ms; matrix, 256×256 or 288×288 ; field of view, 20×20 to 30×30 cm).

The images were analysed digitally using a picture archiving and viewing software (JiveX; Visus, Bochum, Germany). All images were visualised by a senior neuroradiologist and a senior neurosurgeon.

After identification of the spondylolysis, the level was noted. Patients with transitional segments were included in a way that the last free vertebra was labelled as lumbar 5 (L5) and that the transitional vertebra was labelled sacral 1 (S1). If spondylolisthesis was present, the slippage of the spondylolytic vertebra was measured as shown in Figure 1. For this purpose a line was drawn on a midline sagittal image allowing a clear delineation of the bony structures connecting the upper and lower dorsal edge of the cranial vertebra. A second parallel line was drawn by the viewing software after pointing to the upper dorsal edge of the caudal vertebra. The distance between the two lines was thought to be equivalent to the slip in millimetres (Figure 1). A cut-off point of 3 mm was chosen, meaning that slips smaller than 3 mm were not taken into account. This cut-off point was chosen based on image resolution. The slip was recorded in millimetres and then classified according to the Meyerding classification (Table 1).

After that the difference in length between the cranial, spondylolytic vertebra and the adjacent caudal vertebra was measured (Figure 2). A difference in length between the two vertebrae was recorded. Here too only differences equal to or greater than 3 mm were retained. Taking into account the hypoplasia, the classification

after Meyerding was redone in a modified way. After subtracting the hypoplasia from the measured slip, the real slippage was defined as a percentage in relation to the vertebra below (Table 2).

To compare the findings of our study group with patients without spondylolysis or spondylolisthesis, a control group of 141 patients was created. For the control group only patients without spondylolysis or spondylolisthesis were included. Spondylolisthesis was defined as a disturbance of the ventral alignment of the lumbar spine. The control group was recruited from patients randomly picked, who had undergone a lumbar MRI scan for various reasons, mostly unspecific low back pain, between October 2008 and May 2009. Both groups were not matched with each other.

The length of the lower margin of L5 was compared to the length of the upper margin of S1 (Figure 3).

The data were recorded in a datasheet using Excel (Microsoft, Redmond, WA). Statistical analysis was carried out using a paired χ^2 test (Statview; SAS, Cary, NC). The hypothesis tested was that there was no difference in length between the cranial, spondylolytic vertebra and the caudal vertebra in the two groups. The hypothesis could be rejected with $p < 0.001$ using the χ^2 test.

Results

140 patients with spondylolysis or isthmic spondylolisthesis were included in this study. Of these, 102 were male and 38 were female. The mean age was 49 years (range from 11 to 81 years). In 1 patient there was a spondylolysis at two levels, and therefore a total of 141 levels of spondylolysis was analysed. The level of

Table 1. The number of patients according to the different grades after Meyerding for all patients

Grades after Meyerding	Traditional grading
0	22
I	74
II	43
III	1
IV	1
V	0
Total	141

Figure 2. Measurement of the difference in size between the spondylolytic vertebra L5 and S1 is shown in a sagittal midline T_2 weighted scan of the lumbar spine. A similar section is shown with and without the measurements. Two lines from the measurement in Figure 1 are in light grey to show the measured slip of L5 over S1. Line A shows the measurement of the length of L5 at the lower margin. Line B depicts the measurement of the upper margin of S1. Both values are noted in millimetres and the difference in size, showing the shortening of L5, is recorded. L, lumbar; S, sacral.

spondylolysis was level L5/S1 in 122 cases, L4/5 in 14 cases, L3/4 in 4 cases and L2/3 in 1 case. The spondylolysis was unilateral in 8 cases and bilateral in 133 cases.

Spondylolisthesis was diagnosed in 120 patients. The mean range of the slip in the midline sagittal image was 9 mm, with a range of 3–17 mm of slip (Meyerding Grade I–IV). The distribution of the patients according to the Meyerding classification is shown in Table 1.

In 50 patients the vertebral body of the spondylolytic vertebra was shortened in the midline sagittal image compared with the lower, adjacent vertebra. The range of such hypoplasia varied between 3 and 13 mm with a mean of 5 mm. Hypoplasia was only observed at the L5 level.

None of the subjects in the control group had a shortened, hypoplastic vertebra. The vertebrae tended to be of the same size (mean difference <1 mm) (Figure 3).

Shortening was therefore found only in patients with spondylolysis ($p < 0.001$).

Taking into account hypoplasia, the grading had to be adjusted in 33 patients out of the 50 patients with hypoplasia (Table 2). In 19 patients with observed hypoplasia, the measured slip corresponded to the measured shortening. 17 patients formerly graded Meyerding Grade I and 2 patients formerly graded Meyerding Grade II had

to be reclassified as Grade 0. In 14 patients, the grade of slip according to Meyerding had to be adjusted after taking into account the hypoplasia. 13 patients formerly graded Meyerding Grade II were reclassified as Grade I and 1 patient formerly graded Meyerding Grade III was reclassified as Grade II. Hence 66% of the patients with hypoplasia were classified too high when using an unmodified Meyerding classification.

Discussion

The results of our study question the way that isthmic spondylolisthesis is defined and measured.

The original Meyerding classification grading of spondylolisthesis of the cranial vertebra in relation to the lower vertebra does not seem to be valid for isthmic spondylolisthesis on MRI, since hypoplasia or shortening of the cranial, spondylolytic vertebra is not taken into account. Describing a finding as spondylolisthesis rather than spondylolysis is not only a question of taxonomy, but implies a more serious state of the disease. Therefore, the term “spondylolisthesis” should be reserved for patients with a real slip and not a slip mimicked by a shortened, hypoplastic vertebra.

Hypoplasia is a common finding as 50 (42%) of the 120 patients with isthmic spondylolisthesis (as defined by Meyerding) had a shortened vertebral body. In 19 patients out of the 50 patients with hypoplasia no real spondylolisthesis was present and the shortening equalled the measured slip. Even the higher grades of Meyerding II and III were affected by the shortening and the grades thus require adjustment for hypoplasia.

MRI allows the measurement of real distances without distortions and summation with overlying structures, and therefore real distances should be measured. When doing so, however, the image resolution must be taken into account. Because of the size of the field of view and the chosen resolution, a clear point-to-point discrimination is only possible at a distance of 3 mm. Therefore, a slip or a hypoplasia of less than 3 mm had to be discarded as it was not certain whether it was pathological or not. When using high-field MRI units that allow higher matrices to be computed, the point-to-point discrimination increases. Hence the number of patients with a hypoplasia of <3 mm might be higher in other studies. The number of

Table 2. The number of patients according to the different grades after Meyerding for patients with hypoplasia

Grade after Meyerding	Traditional grading	Adjusted grading
0	0	19
I	29	25
II	20	6
III	1	0
Total	50	50

Using the traditional grading system, all patients with hypoplasia have by definition a slip and are hence graded as Meyerding Grade I. Using the adjusted grading system, taking into account the hypoplasia 17 patients formerly graded as Grade I and 2 patients formerly classified Grade II were classified as Grade 0. 13 patients graded as Grade II were reclassified as Grade I. The only patient graded as Grade III was reclassified Grade II. Hence 33 patients out of 50 patients with vertebral hypoplasia had to be reclassified using the adjusted grading system.

Figure 3. Measurement of the difference in size between L5 and S1 is shown in a sagittal midline T_2 weighted scan of the lumbar spine of a patient from the control group. A similar section is shown with and without the measurements. Line A shows the measurement of the length of L5 at the lower margin. Line B depicts the measurement of the upper margin of S1. Both values are noted in millimetres and the difference in size is recorded. L, lumbar; S, sacral.

hypoplastic vertebrae found corresponds well with the findings of other groups [7, 8].

In patients with a suspected spondylolisthesis, the relation of the spondylolytic vertebral body to the vertebra below should always be considered while measuring a slip. The anterior alignment of the spinal column should be noted and in cases of regular alignment, the presence of spondylolisthesis should be questioned. The Meyerding method of defining a slip of a vertebra in relation to the vertebra below seems perfectly suitable if amended that way.

Although the Meyerding method seems to be suitable, this is not the case for the classification without adjustment. The classification was originally described for conventional X-ray imaging, but at that time hypoplasia in spondylolysis and isthmic spondylolisthesis was not known. Even when using conventional X-ray imaging, one should be aware of possible hypoplasia [7, 8]. Since MRI allows the measurement of real distances, real distances should be measured. The description of the slip should include possible hypoplasia and the grading system should be amended. The grading system should not be discarded altogether, since it proved its usefulness in the clinical day-to-day practice and it is useful for comparing groups of patients.

Hypoplastic vertebral bodies in patients with spondylolysis have been described previously, but to our knowledge not with regards defining and measuring a slip [7, 8, 10]. The elongation of the pars interarticularis and the so-called wide canal sign or wedging of the spondylolytic vertebral body have been described in patients with a hypoplastic spondylolytic vertebra [5, 6].

The reason why this finding is not often described in imaging studies is probably because it is not as prominent in the recumbent or standing position. In the recumbent as well as in the standing position, the lumbar spine is in lordosis and therefore the size of the vertebral bodies in relation to each other is more difficult to judge without measuring. In the sitting position, the lumbar spine is straightened and, therefore, in our opinion, differences in the size of the vertebral bodies are more obvious. The sitting position, which allows a clearer comparison of the sizes of vertebral bodies, is however totally unsuited to diagnosing a spinal canal or neuroforaminal narrowing because of the straightening.

The pathogenesis of spondylolysis and isthmic spondylolisthesis is a complex one and the factors leading to spondylolysis and concurrent spondylolisthesis are not fully understood.

Isthmic spondylolysis is a common disorder affecting about 6% of the Caucasian population [11]. A recent investigation found a prevalence of 11.5% in an unselected community-based population in the USA [12]. A family predisposition is known with up to 70% prevalence in first-degree relatives [13]. Sports involving hyperlordosis of the spine are known to promote the development of spondylolysis [4].

The question arising when seeing hypoplasia of the spondylolytic vertebral body is whether it is inborn or acquired. The fact that this change is only observed at the level of L5/S1 could be an indicator that we are looking at an inborn variant.

Such an inborn variant which might predispose for spondylolysis could explain the incidence of spondylolysis in first-degree relatives, family or in some specific populations. Since none of the control group had a shortening of the last free vertebra, such shortening may always lead to fracture or may be rare in the general population. In this case, hypoplasia would be the cause of spondylolysis and isthmic spondylolisthesis.

However, the arguments for an acquired disposition are stronger. One follow-up study with conventional X-ray has shown that the hypoplasia develops over time and is not present from the start [14]. Wilms et al [8] implied that the hypoplasia might be due to increased pressure on the dorsal part of the spondylolytic vertebral body as a result of altered biomechanics after the spondylolysis occurred, and that this might favour the development of spondylolisthesis. Another possibility is that when bones fracture, bone overgrowth tends to occur, especially if the broken bone is not put to rest. Since the spondylolytic vertebra cannot be put to rest, an overgrowth might occur, thus hindering the normal development of the vertebral body. It could be that since the biodynamics in each segment are different, overgrowth may occur more easily in the last segment of the spine. The time the fracture of the pars interarticularis occurred must be important, too, since an overgrowth that hinders the normal development of the vertebral body is only possible in growing patients. Hypoplasia would then be caused by spondylolysis.

Further research is necessary in order to clarify this point. A child with an unbroken elongated pars interarticularis would be worth reporting to clarify this issue.

Another important unknown issue is whether patients with a spondylolysis and hypoplasia are more prone to develop an increase in the slip than patients with spondylolysis and without hypoplasia. Here, too, further research is necessary.

The shortening in the midline sagittal image can be considered the hallmark of spondylolysis and the terms "shortening" or "hypoplasia" should replace the terms "wedging" and "wide canal".

This study offers an intriguing new view on the way to define and measure spondylolisthesis. A shortening of the spondylolytic vertebra is common and it mimics spondylolisthesis. Hence the term "spondylolisthesis" should be reserved for patients with a real difference between a shortened hypoplastic vertebra and a measured slip.

When spondylolisthesis is suspected, cross-sectional imaging should be mandatory in order to confirm or refute the diagnosis. Cross-sectional imaging allows measurements to be made in millimetres without distortion. The slip and a possible hypoplasia should be expressed in millimetres and the Meyerding classification should be amended as discussed.

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