Skeletal Radiol (2000) 29:703–707


ARTICLE

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# Pedicle marrow signal intensity changes in the lumbar spine: a manifestation of facet degenerative joint disease

Received: 2 May 2000
Revision requested: 18 July 2000
Revision received: 25 August 2000
Accepted: 1 September 2000

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**Abstract** *Objective*. Signal intensity changes in lumbar pedicles, similar to those described in vertebral body endplates adjacent to degenerated discs, have been described as an ancillary sign of spondylolysis on MRI. The purpose of this study was to determine whether pedicle marrow signal intensity changes also occur in association with facet degenerative joint disease.
*Design*. Eighty-nine lumbar spine MRI examinations without spondylolysis were reviewed for marrow signal intensity changes in pedicles and vertebral bodies as well as for facet degenerative joint disease.
*Results*. Five percent (46/890) of lumbar pedicles in 23 patients had marrow signal intensity changes. Ninety-one percent (42/46) of the abnormal pedicles had adjacent degenerative joint disease of the facets, while only 21% (189/890) of normal pedicles had adjacent facet degenerative joint disease ($p<0.001$). Eighty-nine percent (41/46) of the pedicles with marrow signal intensity changes had adjacent degenerative disc disease.
*Conclusions*. Pedicle marrow signal intensity changes are not a specific sign of spondylolysis; they are commonly seen with adjacent facet degenerative joint disease in the absence of spondylolysis. Pedicle marrow signal intensity changes are probably a response to abnormal stresses related to abnormal motion or loading caused by the degenerative changes in the spinal segment.

**Keywords** Lumbar spine · Marrow · Degenerative joint disease

## Introduction

Signal intensity changes in bone marrow adjacent to vertebral body endplates associated with degenerative disc disease, as described by Modic et al. [1] are often seen on lumbar spine MRI examinations. These marrow changes are felt to be a result of abnormal mechanics and loading at the level of a degenerated intervertebral disc. Similar marrow signal intensity changes in the vertebral pedicles and pars interarticularis have been described as a useful ancillary sign of spondylolysis [2, 3, 4]. We have routinely noticed marrow signal intensity changes in lumbar pedicles in the absence of spondylolysis. Many of these patients had degenerative joint disease (DJD) of the adjacent facet joints. The purpose of this study was to determine: (1) whether signal intensity changes in pedicles are specific for spondylolysis; (2) if not, whether the pedicle marrow changes are related to adjacent facet DJD; and (3) whether the presence of pedicle marrow changes is associated with vertebral body marrow signal intensity changes related to degenerative disc disease.

## Materials and methods

Eighty-nine consecutive lumbar spine MRI examinations collected over a 6-week period were reviewed. All MRI examinations done for indications of low back pain or radicular symptoms were included; however, patients with malignancy, prior spinal trauma, or spondylolysis were excluded. All scans were performed on a 1.5-T

superconducting magnet (Vision; Siemens, Iselin, N.J.). Sagittal T1-weighted (TR/TE 700/12 ms), sagittal fast spin echo T2-weighted (TR/effective TE 3000/103 ms, echo train length 15) and axial (not angled with the disc) fast spin echo T2-weighted (TR/effective TE 5000/120 ms, echo train length 15) images were reviewed. Section thickness was 4 mm with a 25% gap. The imaging parameters were 354×512 matrix, FOV 14 cm for the T1-weighted sagittal images; 384×512 matrix, FOV 17.5 cm for the fast T2-weighted sagittal images; and 390×512 matrix, FOV 16 cm for the fast T2-weighted axial images.

Pedicles were individually evaluated from L1 through L5 bilaterally for marrow signal intensity changes that varied from the intermediate signal intensity red marrow of the vertebral body at the same level as the pedicle. A classification system previously described for disc-related marrow changes in the vertebral end plates was applied [1, 2]: low signal on T1-weighted and high on T2-weighted images (type I), or high on both T1-weighted and T2-weighted images (type II) similar to fat. Owing to lack of fat suppression on the fast T2-weighted sequences, both type I and II marrow changes could be high signal; however, type I would be low signal on T1-weighted images while type II would be high signal, allowing differentiation of the two types of marrow signal.

Facet joints were evaluated bilaterally from L1–2 through L5–S1. Evaluation of the facets was done independently from evaluation of the marrow in the pedicles. The joints were characterized individually as being normal or having DJD. As no grading system for facet DJD is universally used, the severity of the DJD was not evaluated. Imaging findings that were used to diagnose DJD were loss of cartilage, osteophytosis, subchondral cysts or sclerosis, and synovial cysts arising from the facet joints. A pedicle was considered to be adjacent to a degenerated facet joint if the facet joint complex either superior or inferior to the pedicle (or both) demonstrated degenerative changes. This was done because each pedicle is anatomically related to facet joints at two adjacent levels. For example, an L4 pedicle is related to both the L3/4 facet joint above, and the L4/5 facet joint below.

Spondylolisthesis (on the basis of degenerative changes, and not secondary to spondylolysis) at any lumbar level was also recorded because motion indicates increased stresses involving both the vertebral body and posterior elements, which may be responsible for inciting signal intensity changes in the marrow of pedicles.

The presence of degenerative disc disease and the presence and type (I or II) of vertebral body marrow signal intensity changes were also evaluated and recorded. Decisions regarding all features that were evaluated were made by three musculoskeletal radiologists in consensus. Chi-square analysis was used to determine significance ($P<0.05$).

## Results (Table 1)

### Pedicle marrow changes

A total of 890 lumbar spine pedicles were evaluated in 89 patients. Twenty-three of the 89 (26%) lumbar spines reviewed had pedicle marrow changes. The average age of patients with pedicle marrow changes was 49 years (range 24–71 years). The average age of patients without pedicle marrow changes was 49 years (range 19–79 years). Of the 890 pedicles, 46 (5%) had marrow signal intensity changes; 44 had type II changes (Fig. 1), and 2 had type I (Fig. 2) changes. The abnormal pedicles occurred at the L3, L4 and L5 levels only. One right, four left and two bilateral pedicles were involved at L3. At L4, abnormal pedicles were bilateral in four, only on the right in two and only on the left in three patients. L5 was the vertebra most commonly involved, with seven bilateral pedicles, eight left and two right. The fewest number of affected pedicles in a single person was one; the greatest number of pedicles affected in one individual was six.

### Facet degenerative joint disease

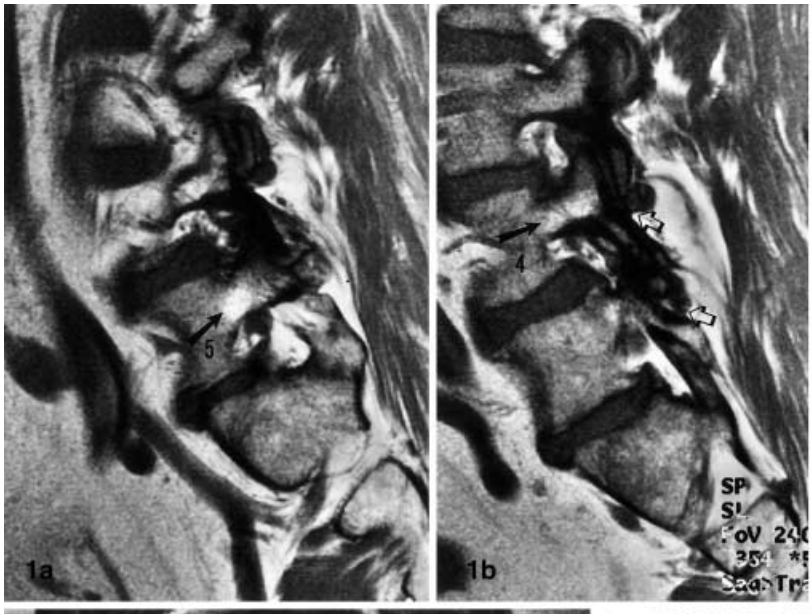
Of the 890 pedicles evaluated, 42 of the 46 (91%) with marrow signal intensity changes had adjacent facet DJD seen by MRI; 189 of the 844 (21.2%) pedicles with normal marrow had adjacent facet DJD by MRI ($P<0.001$). The remaining 655 normal pedicles had normal adjacent facet joints by MRI.

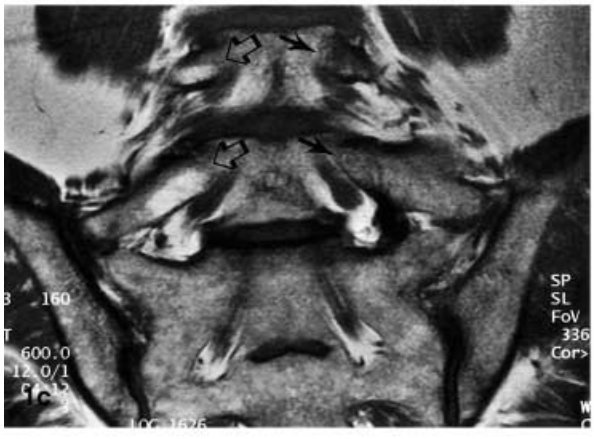
### Vertebral body marrow signal changes

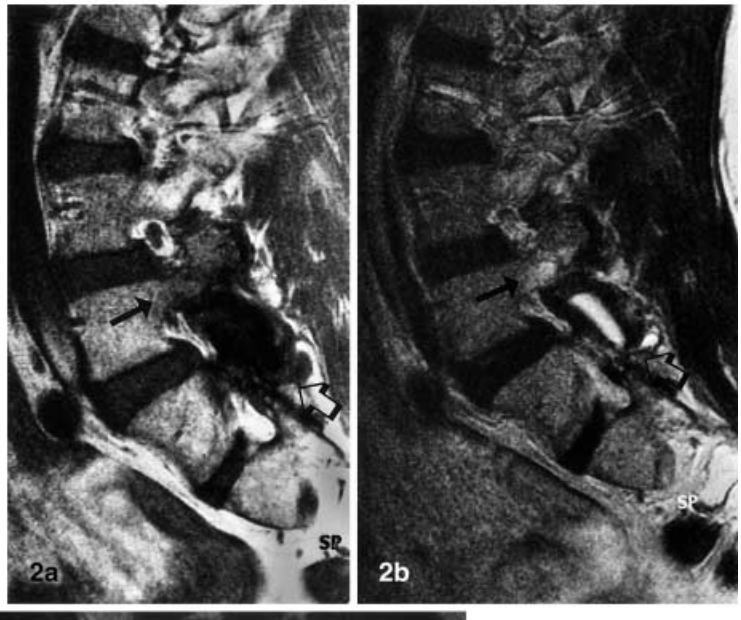
Focal marrow signal intensity changes paralleling the endplates of vertebral bodies, as described by Modic et al. [1], were found in 23 of 89 (26%) lumbar spine MRI examinations. Ten of these 23 people (43%) with vertebral body marrow signal intensity changes had similar changes in their pedicles. A total of 29 vertebral disc levels had marrow signal intensity changes in the adjacent endplates. Of these 29 levels, 11 (38%) had pedicle marrow signal intensity changes at the same level. Of the 46 pedicles with marrow signal intensity changes, 89% (41/46) had degenerative disc disease at an adjacent level while 11% (5/46) had no adjacent degenerative disc disease evident by MRI criteria.

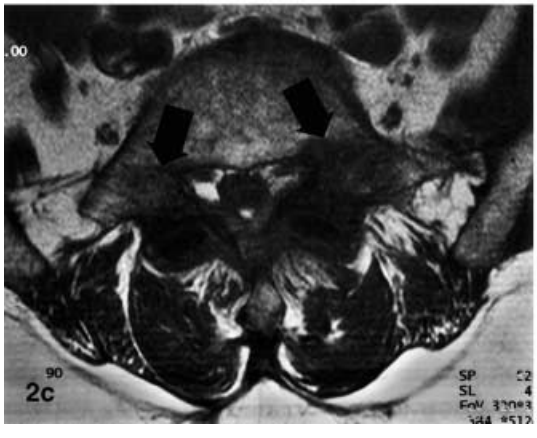
**Table 1** Summary of results (*DJD* degenerative joint disease)

| | |
|---|---|
| Subjects with pedicle marrow changes | 23/89 (26%) |
| Number of pedicles with marrow signal changes | 46/890 (5%) |
| Type I marrow signal changes | 2/46 (4%) |
| Type II marrow signal changes | 44/46 (96%) |
| Levels affected | L3, 9/46; L4, 13/46; L5, 24/46 |
| Facet DJD adjacent to abnormal pedicle | 42/46 (91%) |
| Abnormal pedicle adjacent to normal facets | 4/46 (8%) |
| Facet DJD adjacent to normal pedicle | 189/844 (21%) |



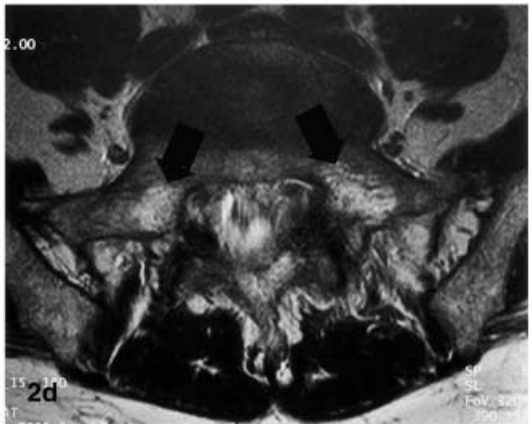




**Fig. 1a–c** A 66-year-old man with low back pain and type II pedicle marrow changes, right L4 and L5. **a** T1-weighted sagittal image through the right L5 pedicle (*arrow*) shows focal high signal fat in the pedicle, and adjacent degenerative joint disease (DJD) of the L4–5 facet joint. **b** T1-weighted sagittal image obtained adjacent to **a**, depicting focal fat in the marrow of the L4 pedicle (*arrow*) with facet DJD at L3–4 and L4–5 (*open arrows*). Normal red marrow is seen in the L3 pedicle. **c** Coronal T1-weighted image demonstrates focal fat in the marrow of the right L4 and L5 pedicles (*open arrows*) with normal red marrow in the left L4 and L5 pedicles for comparison (*filled arrows*)

Degenerative spondylolisthesis

Spondylolisthesis was present at 18 levels in 13 of the 89 lumbar MRI examinations reviewed (15%). Three of these 18 levels (17%) had adjacent pedicles with marrow signal intensity changes. At levels with spondylolisthesis, 12 of 18 (67%) had facet DJD at the same level by MRI.

## Discussion

Signal intensity changes in the marrow of vertebral bodies that parallel adjacent degenerative disc disease have been well described [1, 5]. The radiologic/pathologic investigations by Modic et al. [1] showed marrow fibrovascular changes or fatty conversion (type I and type II signal changes, respectively) in the vertebral bodies adjacent to a degenerated disc in 20% of their study group. The hypothesis is that the bone marrow reacts in response to increased stress on the bone caused by the abnormal motion and decreased shock absorption of a degenerated disc.

Focal marrow signal intensity changes similar to those in vertebral bodies can be seen in pedicles and the pars interarticularis at the level of a pars defect (spondylolysis) [2, 3, 4]. Marrow signal intensity changes in the pedicles adjacent to the spondylolysis have been described as a useful ancillary sign of spondylolysis which may allow an increased sensitivity for diagnosing spondylolysis by MRI [2, 4, 6, 7]. A study by Ulmer et al. [4] which compared the different ancillary signs of spondylolysis, found pedicle marrow signal changes to be the least common ancillary sign.

Although we saw pedicle marrow signal intensity changes related to adjacent spondylolysis when routinely reading lumbar spine MRI examinations, we more often saw the marrow changes in the pedicles when no spondylolysis could be identified or proven by MRI, computed tomography, or conventional radiography. This led us to believe that increased stresses on the pedicles from causes other than spondylolysis must result in pedicle marrow changes. The most likely source for increased stresses and altered biomechanics on the pedicles is motion of a spinal segment, which commonly occurs from degenerative disc disease and/or facet DJD. We hypothesize that abnormalities of the facet joints, rather than the discs, would be most likely to affect the marrow of an adjacent pedicle owing to the proximity of the two structures. However, degenerative changes in the discs and facet joints often coexist, and it is not possible to be certain which abnormal structure contributes more to abnormal stresses on the adjacent pedicles.

Our review of lumbar spine MRI examinations for this investigation showed that signal intensity changes in the marrow of lumbar pedicles is not a specific sign for spondylolysis; instead, these changes are often associated with DJD of the adjacent facet joint. In our study group, 91% (42/46) of lumbar pedicles with marrow signal intensity changes had adjacent facet DJD. Only 9% (4/46) of lumbar pedicles with marrow signal intensity changes had no imaging evidence of adjacent facet DJD. Conversely, only 21% of pedicles with unaltered marrow signal (marrow with an appearance identical to that of the red marrow of the vertebral bodies) had evidence of DJD of the adjacent facet joints.

Eighty-nine percent of the pedicles with marrow signal intensity changes had associated degeneration of an adjacent intervertebral disc. This further indicates that there are abnormal stresses created by degeneration of the spinal segment in those who have marrow signal intensity changes in their pedicles. It is not surprising that nearly half the patients with marrow signal changes in their vertebral bodies also had similar changes in their pedicles. The pedicle and vertebral body marrow changes were present in the same vertebral level in 37% (17/46) of the pedicles affected.

Degenerative changes in discs and facet joints increase with age. Conversion from red to yellow marrow is also an age-related phenomenon. Focal conversion related to aging may create islands of yellow marrow such as the type II changes we described in the pedicles. However, it is highly unlikely that the pedicle marrow changes are due to age-related conversion rather than to increased stresses from facet DJD for several reasons. There is no reason for conversion to occur preferentially in the lower lumbar pedicles rather than the upper level pedicles, yet facet DJD is far more common in the lower lumbar pedicles where the pedicle marrow changes also predominated. In addition, age-related marrow conversion does not account for the type I marrow changes we found in pedicles. Lastly, there was no age difference between the group with pedicle marrow changes and the group with normal pedicle marrow signal.

Because our routine lumbar spine protocol utilizes a fast T2-weighted sequence without fat saturation, both type I (fibrovascular changes) and type II (fatty conversion) marrow signal changes appear as high signal. This

◀ **Fig. 2a–d** A 65-year-old woman with low back pain and bilateral type I pedicle marrow changes at L4. **a** T1-weighted sagittal image shows focal low signal (*filled arrow*) in the L4 pedicle. There is severe adjacent DJD of the L4–5 facet joint (*open arrow*) with hypertrophic changes, and sclerosis. **b** Fast T2-weighted sagittal image at the same level as in **a** demonstrates focal high signal (*filled arrow*) in the L4 pedicle relative to the vertebral body. The DJD of the L4–5 facet joint is manifest by excessive joint fluid and a small posteriorly projecting synovial cyst (*open arrow*). **c** Axial T1-weighted image through the L4 pedicles shows bilateral focal pedicle marrow changes with low signal in the pedicles (*arrows*), more pronounced on the left than the right side. **d** Fast T2-weighted axial image at the same level as in **c** shows high signal in the pedicles from type I marrow changes (*arrows*)

is an inconsequential limitation, since the differentiation between types I and II is obvious on the T1-weighted sequence where type I is low signal and type II changes are high signal (fat). Furthermore, there is no clinical significance in differentiating between the two types of marrow signal intensity.

Patients with degenerative spondylolisthesis did not have a higher frequency of marrow signal intensity changes in the pedicles than those without the spondylolisthesis, although the motion that must be present to cause the subluxation of one vertebral segment on another is a clear indication of increased stresses.

Why some people develop these pedicle marrow changes while others with similar degenerative changes of their discs or facet joints do not, is not known; however, if marrow changes are present in the vertebral bodies, there is a 50% likelihood that they may also be found in the pedicles, or vice versa.

There is a differential diagnosis for marrow signal intensity changes of pedicles. In addition to degenerative spondylosis and spondylolysis related to a defect of the pars interarticularis, pedicle marrow signal abnormalities may be seen with metastatic disease, osteoid osteoma, fracture, or post-operative changes [3, 8].

In conclusion, marrow signal intensity changes in lumbar pedicles are not specific for spondylolysis but are often associated with the much more common process of facet degenerative joint disease. Development of this type of marrow response is probably due to the abnormal stresses placed on the posterior elements by degeneration of the adjacent facet joints and/or intervertebral disc.

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