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The relationship between facet joint osteoarthritis and disc degeneration of the lumbar spine: an MRI study

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Abstract The role of MRI in assessing facet joint osteoarthritis is unclear. By developing a grading system for severity of facet joint osteoarthritis on MRI, the relationship between disc degeneration and facet joint osteoarthritis was determined. The accuracy of MRI in assessing facet joint osteoarthritis against CT was 94%. Under 40 years of age, the degree of disc degeneration varied among individuals. Over the age of 60, most of the discs were markedly degenerated. Under 40 years of age osteoarthritic changes in facet joints were minimal. Over the age of 60, variable degrees of facet joint osteoarthritis were observed but some facets did not show osteoarthritis. No facet joint osteoarthritis was found in the absence of disc degeneration and most facet joint osteoarthritis appeared at the intervertebral levels with advanced disc degeneration. Disc degeneration is more closely associated with aging than with facet joint osteoarthritis. The present study supports the hypothesis that "disc degeneration precedes facet joint osteoarthritis", and also supports the concept that it may take 20 or more years to develop facet joint osteoarthritis following the onset of disc degeneration.

Key words MRI · Disc degeneration · Facet joint · Osteoarthritis · Lumbar spine

Introduction

The intervertebral disc and facet joints form the functional spinal unit, and disc degeneration and facet joint osteoarthritis play an important role in spinal degeneration [20, 31]. Previous studies have demonstrated that the incidence of these changes increases with age [1, 2, 4, 5, 7, 9, 11, 17–19, 21, 23, 25, 28, 33, 36, 37, 39], and disc degeneration usually proceeds facet joint osteoarthritis [2, 15, 24, 30, 37]. MRI is the diagnostic test of choice in evaluating disc degeneration. Disc degeneration has traditionally been graded by either gross morphological observation or MRI [12]. MRI may not evaluate facet joint osteoarthritis as accurately as CT [16, 26]. There has been only one report that examined the accuracy of routine MRI in assessing facet joint osteoarthritis of the lumbar spine [40]. One of the purposes of this study is to evaluate the accuracy of MRI in assessing facet joint osteoarthritis. Another aim of this study is to determine the relationship between disc degeneration and facet joint osteoarthritis. By developing a grading system for facet joint osteoarthritis, the relationship between disc degeneration and facet joint osteoarthritis can be determined more accurately.

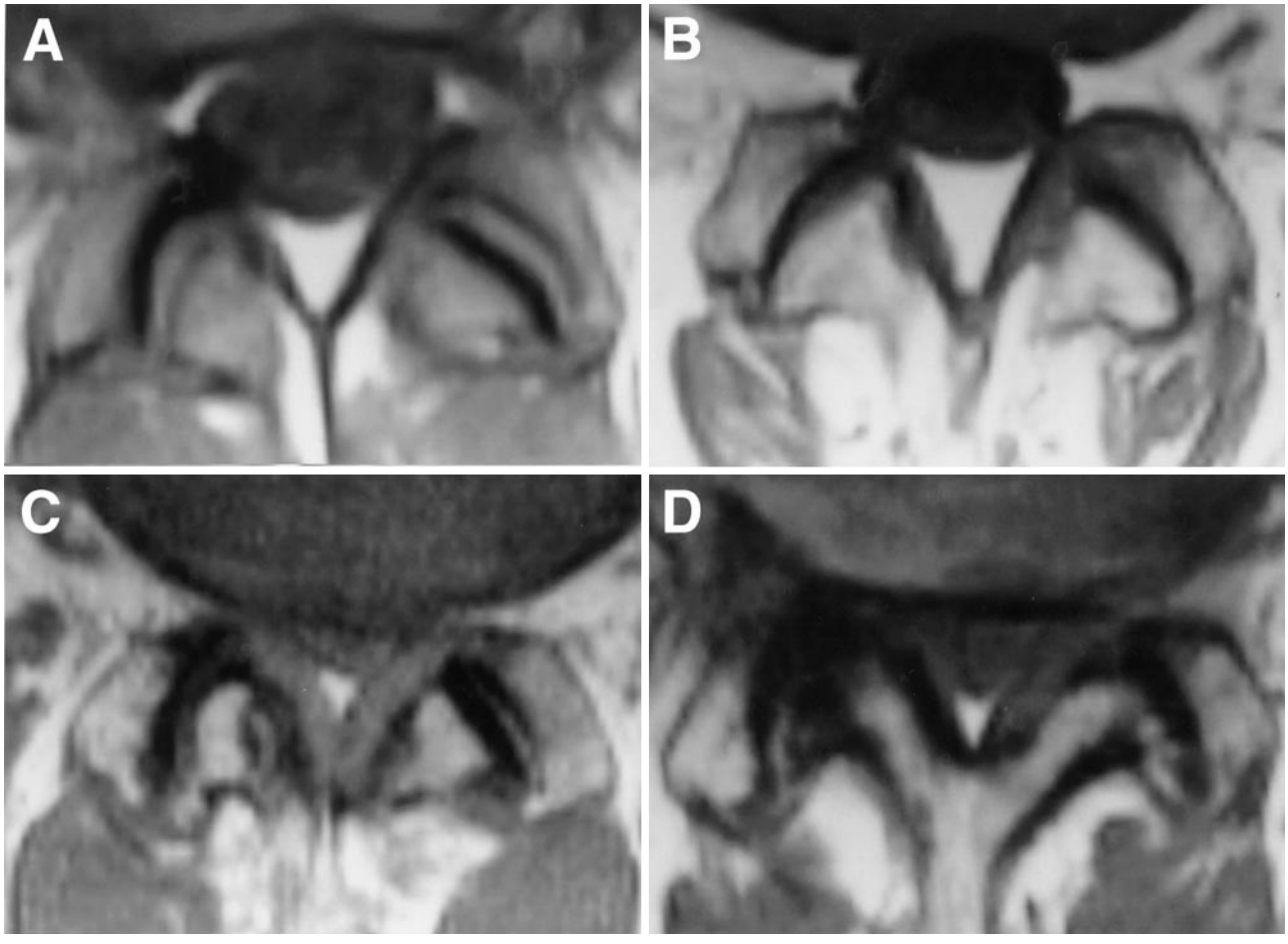

Fig. 1 A–D Four grades of facet joint osteoarthritis on MRI (TR = 570 ms/TE = 15 ms, 5 mm thickness). **A** Grade 1: normal. **B** Grade 2: joint space narrowing or mild osteophyte. **C** Grade 3: sclerosis or moderate osteophyte. **D** Grade 4: marked osteophyte

Materials and methods

Assessment of facet joint osteoarthritis on MRI

In order to evaluate the accuracy of MRI in assessing facet joint osteoarthritis, 84 lumbar facet joints from 14 consecutive patients with degenerative disc disease, who were candidates for lumbar spine surgery, were analyzed by both MRI (a 1.5-T unit, Shimadzu 150SMT) and CT (Xforce or TCT-900S, Toshiba). The average age of the patients was 52.7 years (range, 22–75 years). There were seven male and seven female patients. Both CT and MRI images were obtained parallel to disc spaces at L3-4, L4-5, and L5-S1 levels, with 5-mm consecutive slice thickness. Spin echo T1-weighted axial images (TR = 570 ms/TE = 15 ms, 5 mm thickness) and bone window images from CT were analyzed. The degrees of osteoarthritis on CT and MRI were scored on the same four-point scale according to the Pathria's criteria for grading of facet joint osteoarthritis on CT [32], in which grade 1 (Fig. 1A) = normal, grade 2 (Fig. 1B) = mild (joint space narrowing or mild osteophyte), grade 3 (Fig. 1C) = moderate (sclerosis or moderate osteophyte), grade 4 (Fig. 1D) = severe (marked osteophyte). For the image quality standard, one experienced musculoskeletal radiologist reviewed the CT images and scored them according to the scale. In order to simulate practising physicians interpreting MRI, two orthopaedic surgeons independently reviewed the MR images and blindly graded them according to the same scale. Interobserver agreement, the sensitivity, specificity and accuracy of MRI for assessing facet joint osteoarthritis were calculated against the CT results.

Relationship between disc degeneration and facet joint osteoarthritis

There were 183 consecutive patients with low back pain and/or leg symptoms, who were referred to our hospital and underwent both MRI (SHIMADZ SMT 150GUX, 1.5 T) and x-rays of the lumbar spine. Patients with previous back surgery, congenital anomalies, or infectious, traumatic or tumorous disorders were excluded. The average age was 46.8 ± 18.2 years, ranging from 13 to 81 years. Eighty-eight patients were male and 95 were female. The lower three lumbar levels, L3-4, L4-5, and L5-S1, were examined. Disc degeneration was classified into five grades on T2-weighted midsagittal images (TR = 3200 ms, TE = 100 ms, 5 mm thickness), according to the grading system proposed by Thompson et al. [12]. In this system, disc degeneration grade is determined by the degenerative status of the nucleus, annulus, endplate and vertebral body. If the grading was not consistent among different structures, disc degeneration grade was represented by the degenerative status of the nucleus. Facet joint osteoarthritis was divided into four grades on axial spin echo T1-weighted images using our criteria. When there was a difference in the severity of facet joint osteoarthritis between right and left at the same motion segment, the worst grade was

recorded. All the images were reviewed by one of the authors. To minimize the bias that severe disc degeneration might be assumed to be accompanied facet joint osteoarthritis, disc degeneration and facet joint osteoarthritis were scored independently.

Mean age was determined at each grade of disc degeneration and facet joint osteoarthritis, and the differences between the grades were analyzed with one-way ANOVA. The median grade of disc degeneration and facet joint osteoarthritis was calculated at each intervertebral level. The differences between sexes were analyzed with the Mann-Whitney test, and the differences between the different intervertebral levels were tested with the Kruskal-Wallis test. The correlation between disc degeneration and facet joint osteoarthritis was examined with Kendall's tau-b test. The criterion for statistical significance was $P < 0.05$.

Results

Assessment of facet joint osteoarthritis on MRI

A total of 82 facet joints were evaluated on both CT and MRI. On CT scans, 30 joints (37%) were considered to be grade 1, 19 (23%) grade 2, 25 (31%) grade 3, and 8 (9.8%) grade 4. On MR images, reader 1 considered 36 joints (44%) as grade 1, 28 joints (34%) as grade 2, 12 joints (15%) as grade 3, and 6 joints (7%) as grade 4. On the other hand, reader 2 considered 29 joints (35%) as grade 1, 36 joints (44%) as grade 2, 11 joints (13%) as grade 3, and 6 joints (7%) as grade 4.

Of the 52 facet joints regarded as having osteoarthritis on the basis of CT findings, MR indicated some osteoarthritis in 46 joints for reader 1 and in 51 joints for reader 2. Of the 30 facet joints regarded as normal on CT, MR indicated they were normal in 28 joints for reader 1 and in 26 joints for reader 2. Thus, sensitivity for MRI to assess facet joint osteoarthritis was 88 and 98% for readers 1and 2, respectively, specificity was 90 and 87%, respectively, and accuracy was 93 and 94%, respectively.

Regarding MRI, there was perfect interobserver agreement in 62 of 82 joints (76%), and agreement to within one grade in an additional 20 joints (24%). The calculated kappa value for perfect agreement was 0.636.

Disc degeneration and facet joint osteoarthritis

There were no significant differences in mean age between male and female patients (male: 48.0 years, female: 45.7 years). There were 183 intervertebral levels in L3-4, 181 in L4-5, and 173 in L5-S1. Table 1 shows the frequency of each grade of disc degeneration and facet joint osteoarthritis. Forty-seven percent was rated grade IV disc degeneration, while 62% was rated grade 1 facet joint osteoarthritis.

There was no significant sex difference in the grade of disc degeneration at each intervertebral level. There was also no significant sex difference in the grade of facet joint osteoarthritis at each intervertebral level.

Table 1 Frequency of **A** disc degeneration and **B** facet joint osteoarthritis. The values are number of motion segments (percent)

A Disc degeneration				
Grade I	Grade II	Grade III	Grade IV	Grade V
61 (11.4%)	79 (14.7%)	89 (16.6%)	250 (46.6%)	58 (10.8%)
B Facet joint osteoarthritis				
Grade 1	Grade 2		Grade 3	Grade 4
335 (62.4%)	128 (23.8%)		51 (9.5%)	23 (4.3%)

Table 2 Relationship between disc degeneration and facet joint osteoarthritis. The values are number of motion segments

		Facet joint osteoarthritis				
		Grade 1	Grade 2	Grade 3	Grade 4	Total
Disc degeneration	Grade I	61	0	0	0	61
	Grade II	77	1	1	0	79
	Grade III	66	18	5	0	89
	Grade IV	117	85	36	12	250
	Grade V	14	24	9	11	58
	Total	335	128	51	23	537

There was a significant correlation between disc degeneration and facet joint osteoarthritis ($P < 0.001$)

The median of disc degeneration grade at the L3-4 intervertebral level was significantly lower than that at the L4-5 and L5-S1 levels ($P < 0.001$), while there was no significant difference in the grade of disc degeneration between L4-5 and L5-S1. The median grade of facet joint osteoarthritis at L4-5 was significantly higher than that at L3-4 ($P < 0.05$), while no significant differences were found between L3-4 and L5-S1, and between L4-5 and L5-S1.

Regarding the severity of disc degeneration as a function of age, the degree of disc degeneration varied among individuals under 40 years of age. Over the age 60, most of the discs were markedly degenerated. These trends are similar at each spinal level. The mean age of each grade of disc degeneration at the L4-5 level was 23.1 years for grade I, 35.5 years for grade II, 41.8 years for grade III, 52.2 years for grade IV, and 61.8 years for grade V. The mean age significantly increased with the progression of disc degeneration grade, except for the difference between grades II and III (I vs II, III vs IV, and IV vs V were $P < 0.05$; I vs III, I vs IV, I vs V, II vs IV, II vs V, and III vs V were $P < 0.001$).

As for the prevalence of facet joint osteoarthritis, osteoarthritic changes in facet joints were minimal under 40 years of age. After that age facets gradually degenerated. Over the age of 60, variable degrees of facet joint osteoarthritis were observed, but some facets did not show osteoarthritis. These observations were similar at each spinal level. The mean age of each grade of facet joint os-

teoarthritis at the L4-5 level was 35.9 years for grade 1, 57.5 years for grade 2, 65.5 years for grade 3, and 68.8 years for grade 4. The mean age increased with the progression of facet joint osteoarthritis; however, statistical significance was found only between grade 1 and all other grades ($P < 0.001$), and between grades 2 and 4 ($P < 0.05$).

Table 2 shows the relationship between disc degeneration and facet joint osteoarthritis. No facet joint osteoarthritis was found in the absence of disc degeneration. Furthermore, most facet joint osteoarthritis appeared at the intervertebral levels with grade IV or V disc degeneration. There was a significant correlation between severity of disc degeneration and facet joint osteoarthritis ($P < 0.001$). The calculated correlation coefficient value was 0.584 at the L3-4 level, 0.460 at the L4-5 level, and 0.310 at the L5-S1 level.

Discussion

Assessment of facet joint osteoarthritis on MRI

The facet joints have diarthrodial synovial articulation, and undergo degenerative changes identical to osteoarthritis seen in other synovial articulations [23, 37]. These osteoarthritic changes are pathologically defined as cartilage loss, subchondral bone sclerosis, and osteophyte formation. Conventional radiography still remains a common screening method to evaluate these changes, but has significant limitations in detecting early facet joint osteoarthritis [32]. CT can depict the facet joint in the axial plane and has accurately demonstrated the osteoarthritic changes of the facet joint [3]. MRI also can provide axial and sagittal images of the lumbar facet joints in degenerative spinal disease [16]. However, the MR capability of depicting facet joint osteoarthritis has been less examined in the literature [22, 40].

Weishaupt et al. [40] examined the accuracy of facet joint osteoarthritis against CT. They reported that the MR accuracy in assessing facet joint osteoarthritis was 95%, although they used T2-weighted spin echo images. The present study supported their results and demonstrated the 93% accuracy. Pathria et al. [32] devised the grading system of facet joint osteoarthritis on CT, in a series where 65% of the patients, with the mean age of 52.8 years, had facet joint osteoarthritis. Butler et al. [2] confirmed the presence of facet joint osteoarthritis using CT; 21% of their patients, with a mean age of 41.8, showed osteoarthritis. In our MRI study, the patients' mean age was 46.8 years and the prevalence of facet joint osteoarthritis was 38%, which was consistent with previous CT studies.

Our results also showed that MRI tends to underestimate the severity of osteoarthritis as compared with CT. MRI is less sensitive in depicting the bony cortex margin, and thinning of the cartilage can not be measured accurately with MRI because of partial volume effect and chemical-shift artifact [16, 22]. Nevertheless, the accuracy and interobserver agreement of MRI for assessing osteoarthritis of the lumbar facet joints are acceptable. Therefore, for the most part, MRI can be a substitute for CT in assessing osteoarthritis of the lumbar facet joints.

Disc degeneration and facet joint osteoarthritis

Many postmortem and radiographic studies have shown a close relationship between disc degeneration and aging. Males tend to have more disc degeneration than females [21, 25], and the L4-5 and L5-S1 levels are more degenerated than the L3-4 level [19, 28]. On the other hand, in a study of a large sample of autopsies, Miller et al. [25] found that the L3-4 and L4-5 discs were more degenerated than the L5-S1 discs. MRI studies have also shown a clear association between disc degeneration and aging. As expected, our study also showed that there is a relationship between disc degeneration and aging. The L4-5 and L5-S1 discs were more significantly degenerated than the L3-4 discs in our study.

The prevalence of facet joint osteoarthritis also increases with age. Lewin [23], in his comprehensive anatomic review of lumbar synovial joints, stated that facet joints showed only minor chondral changes before the age of 45. After that age, advanced chondral changes, subchondral sclerosis and osteophytes became common phenomena. The present study demonstrated a similar prevalence of facet joint osteoarthritis. Previous studies [18, 23] and our study showed that the L4-5 facet joints were more degenerated than any other level, and no sex difference was noted.

Many studies point to the intervertebral disc as the initial site of spinal degeneration, as facet joints degenerate as a result of disc degeneration. Vernon-Roberts and Pirie [37] dissected more than 100 lumbar spines and concluded that disc degeneration was the primary event leading to osteophyte formation and to facet joint changes. They also determined that there was an inverse relationship between severity of osteoarthritis and the preservation of the disc structure. On the other hand, Lewin [23] concluded that apart from the L5-S1 motion segment, disc degeneration did not seem to be the sole or dominant factor predisposing to the onset and development of osteoarthritis of the lumbar synovial joints.

A biomechanical study showed that pressure between facets increased significantly with narrowing of the disc space [8]. Experimental models also showed that disc degeneration preceded the development of facet joint osteoarthritis. In a study of a stab incision model for experimental disc degeneration, Lipson and Muir [24] found microscopic osteoarthritis of the facet joints as a consequence of disc degeneration. In another experimental disc degeneration model after injection of chymopapain, the initial disc space narrowing led to secondary facet joint os-

teoarthritis [15, 30]. However, even at 12–13 months after the injection of chymopapain, osteophyte formation of the facet joint was not observed [30]. Similarly, Moore et al. [27] observed the changes in the facet joints after making an annular tear of sheep lumbar discs. They found osteoarthritis identical with that of humans, but did not observe severe osteoarthritis even after 18 months follow-up.

Butler et al. [2] used MRI to determine disc degeneration and CT scans of the same patients to determine the occurrence of facet joint osteoarthritis, and concluded that discs degenerated before facets. On the other hand, Videman et al. [39] showed that in 20% of degenerative spines, facet degeneration preceded disc degeneration. Our results showed that facet joint osteoarthritis was not found without disc degeneration. Furthermore, most facet joint osteoarthritis was associated with the grade IV or V disc degeneration. Therefore, the present study supports the hypothesis that "disc degeneration precedes facet joint osteoarthritis". This study also supports the concept that it may take many years to develop facet joint osteoarthritis following the onset of disc degeneration.

Our study also showed that aging affects the severity of disc degeneration more than facet joint osteoarthritis. Even in patients with grade V disc degeneration, 14/58 patients showed no facet joint osteoarthritis. Some possible risk factors for disc degeneration have been proposed. However, little is known about the risk factors for facet joint osteoarthritis [13, 14, 35]. Orientation of the lumbar facet joint and its asymmetry (tropism) are risk factors that may have associations with both disc degeneration and facet joint osteoarthritis [6, 10, 29]. The disc clearly affects the biomechanics of the facet joints and disc degeneration affects the facet joints adversely [8, 31]. However, as the structures of disc and facet joint significantly differ from each other, the risk factors and degenerative processes should not be the same. These structural differences may be a possible explanation for the discrepancy of the onset and course of degeneration between the disc and facet joint.

The present study has certain limitations. Routine MRI, even CT, can not detect early changes of facet joint osteoarthritis, such as minor chondral changes and synovial inflammation. Clinically, it is important to know whether the facet joint is painful or not. In this respect, there may be a limit to imaging studies based on the morphological changes of facet joint osteoarthritis. Schulitz et al. [34] reported a high frequency of enhancement of the synovia in the facet joints (facetitis) in patients with lumbago or disc herniation. Their study may give a clue to the detection of painful facet joints. Further studies are needed in assessing the morphology and pathogenesis of facet joint osteoarthritis.

Conclusions

This paper showed that MRI is a reasonable tool for assessment of facet joint osteoarthritis. A grading system to assess the severity of the facet joint osteoarthritis is presented. This grading system can be helpful in research as well as clinically. The relationship between disc degeneration and facet joint osteoarthritis is an expected finding, but this paper showed that disc degeneration is more closely associated with aging than with facet joint osteoarthritis. It is clear that discs degenerate prior to facets become arthritic, and facet joint osteoarthritis is usually associated with advanced disc degeneration.

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