The Differences in Imaging Findings Between Painless and Painful Osteoarthritis of the Hip

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Hiroaki Kijima[1,2], Shin Yamada[2], Natsuo Konishi[2], Hitoshi Kubota[2], Hiroshi Tazawa[2], Takayuki Tani[2], Norio Suzuki[2], Keiji Kamo[2], Yoshihiko Okudera[2], Masashi Fujii[1,2], Ken Sasaki[2], Tetsuya Kawano[2], Yosuke Iwamoto[1,2], Itsuki Nagahata[1,2], Takanori Miura[2], Naohisa Miyakoshi[1] and Yoichi Shimada[1,2]

[1]Department of Orthopedic Surgery, Akita University Graduate School of Medicine, Akita, Japan.
[2]Akita Hip Research Group, Akita, Japan.

ABSTRACT

PURPOSE: In osteoarthritis of the hip, the pain may be strong even if the deformity is mild, but the pain may be mild even if the deformity is severe. If the factors related to the pain can be identified on imaging, reducing such factors can alleviate the pain, and effective measures can be taken for cases where surgery cannot be performed. In addition, imaging findings related to the pain are also important information for determining the procedures and the timing of surgery. Thus, the purpose of this study was to identify the differences in features of osteoarthritis seen on imaging between painless and painful osteoarthritis of the hip.

METHODS: The subjects were the patients with hip osteoarthritis who visited our department in 2015 and who underwent x-ray, computed tomography (CT), and magnetic resonance imaging (MRI), a total of 29 patients (54 hip joints; mean age 63 years; 8 males and 21 females). The degree of osteoarthritis was determined using the Tönnis grade from the x-ray image. The cartilage morphology, intensity changes of bone marrow on MRI (subchondral bone marrow lesions [BMLs]), osteophytes, joint effusions, and paralabral cysts were scored based on the Hip Osteoarthritis MRI Scoring System (HOAMS). The cross-sectional area of the psoas major muscle at the level of the iliac crest was measured on CT, and the psoas index (PI; the cross-sectional area ratio of the psoas major muscle to the lumbar 4/5 intervertebral disc) was calculated to correct for the difference in physique. Then, the relationships between these and visual analog scale (VAS) scores of pains were evaluated.

RESULTS: The average VAS was 55.4 ± 39 mm. The PI and all items of HOAMS correlated with the VAS. The average VAS of Tönnis grade 3 osteoarthritis was 75.8 ± 26 mm. When investigating only Tönnis grade 3 osteoarthritis, the differences between cases with less than average pain and those with above average pain were the BML score in the central-inferior femoral head ($P = .0213$), the osteophyte score of the inferomedial femoral head ($P = .0325$), and the PI ($P = .0292$).

CONCLUSION: Investigation of the differences between painless and painful osteoarthritis of the hip showed that the cases with more pain have BMLs of the femoral head on MRI that extend not only to the loading area, but also to the central-inferior area. Even with the same x-ray findings, the pain was stronger in patients with severe psoas atrophy. Thus, the instability due to muscle atrophy may also play a role in the pain of hip osteoarthritis.

KEYWORDS: Hip osteoarthritis, pain, magnetic resonance imaging

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CORRESPONDING AUTHOR: Hiroaki Kijima, Department of Orthopedic Surgery, Akita University Graduate School of Medicine, 1-1-1, Hondo, Akita 010-8543, Japan. Email: h-kijima@gd5.so-net.ne.jp

Background

In osteoarthritis of the hip, cases may sometimes be painful with only slight deformity on x-rays, whereas cases may sometimes have less pain with severe deformity on x-ray findings. If the factors related to the degree of pain were to be identified, reducing them may help alleviate the pain. Then, in cases where surgery cannot be performed or where surgery must be delayed, effective treatment can be performed for the pain itself, rather than joint structure seen on imaging. Alternatively, if the factors that cause the pain can be found, they become very important information not only to consider conservative treatment options for pain, but also to determine the kind of surgical procedure or the timing of surgery. Furthermore, the information is useful for explaining the subsequent course of the pain and the treatment to the patients.

It is desirable that such information be evaluable on images that can be taken at each hospital. Then, to use such information as parameters related to the degree of pain, it is necessary that the index can be easily measured and have high reproducibility.

Imaging findings related to the pain of hip osteoarthritis include the intramedullary intensity changes in the acetabulum or femoral head on magnetic resonance imaging (MRI),[1-4] so-called bone marrow lesions (BMLs), and muscle atrophy around the hip joint.[5-7] A comprehensive scoring system of MRI findings in hip osteoarthritis, the Hip Osteoarthritis MRI Scoring System (HOAMS), has also been established.[1,8]

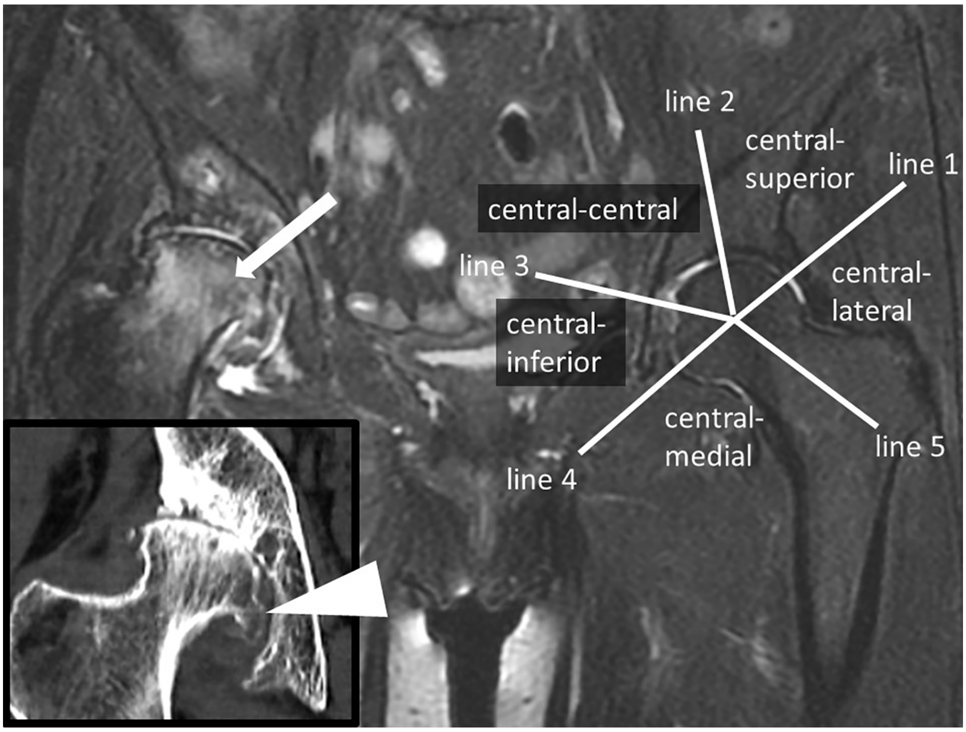

Figure 1. Subregional joint division for scoring of bone marrow lesions (BMLs). Two lines connect the centre of the femoral head with the lateral-superior (line 1) and the medial-inferior (line 4) osseous-labral junction of the acetabulum. The acetabular-sided crescent between these 2 lines is divided into equal thirds by 2 other lines (lines 2 and 3) that also originate in the centre of the femoral head. An additional line (line 5) that runs from the centre of the femoral head laterally and parallel to the femoral neck is drawn. These 5 lines divide the acetabulum into 3 areas and the femoral head into 8 areas. The degree of intensity change in these 8 areas was scored. BML indicates bone marrow lesions; MRI, magnetic resonance imaging.
In the right hip, the intensity change of the bone marrow on magnetic resonance imaging (MRI) extends not only to the loading part, but also to the central-inferior part of the femoral head (arrow). Osteophytes are present at the inferomedial site of the femoral head on MRI and in the computed tomography image (arrowhead).

However, the HOAMS is very complicated, and it takes time to evaluate and score all findings. In addition, its reproducibility may be poor due to the large number of items.[8]

As for the evaluation of the muscles around the hip joint, measurement of the cross-sectional area is mainly used as an index that can be evaluated on imaging. When measuring the cross-sectional area of the muscles around the hip joint, measurement error is less likely to occur in the psoas major muscle having a constant running direction than in the gluteus medius muscle, which tends to vary depending on how the image slice is cut. Semciw et al[9] reported the accurate measurement method of gluteal muscle size; however, in this method the fascial border of each muscle was traced manually in each axial slice. Thus, this method is too complicated in daily clinical setting. Although there is a report of the relationship between pain and the cross-sectional area of the psoas major muscle,[10] this report evaluated the difference between the unaffected side and the affected side. Therefore, this method cannot be used for cases in which both sides have hip osteoarthritis. Muscles other than the iliopsoas muscle also show atrophy in hip osteoarthritis; however, the psoas major muscle was adopted in this study because it is the easiest to measure the cross-sectional area.

Therefore, the present study investigated as many items of the HOAMS as possible and the physique-corrected cross-sectional area of the psoas major muscle as candidates for the imaging findings related to the degree of pain in hip osteoarthritis. If the imaging findings that are clearly related to the pain of hip osteoarthritis could be identified, it would be possible to easily evaluate the causes of that pain by checking only those items in daily practice.

Materials and Methods

The bilateral hips of patients who had undergone preoperative evaluation of their pain level using the visual analogue scale (VAS) and both computed tomography (CT) and MRI of the hip joint, among patients with osteoarthritis who underwent surgery in our department from January to December 2015, were evaluated. However, hips that had already undergone surgery were excluded from this study. That is, all patients who have undergone the above-mentioned examination are included, and the exclusion criterion is only the history of hip surgery.

First, the degree of osteoarthritis was determined using the Tönnis grade[11] from the x-ray image of bilateral hip joints. Next, based on the HOAMS,[1,8] the degree of cartilage damage (cartilage morphology), the degree of intensity changes of bone marrow (bone marrow lesions, BMLs), the degree of osteophytes, the degree of joint effusion, and the degree of paralabral cysts were scored for each site on MRI images (Figure 1). In addition, the cross-sectional area of the psoas major muscle at the height of the iliac crest and the cross-sectional area of the lumbar 4/5 intervertebral disc on CT were measured using Synapse5 (ver. 5.4.001) DICOM Editor software (FUJIFILM Medical Co., Ltd., Tokyo, Japan), and the ratio of the cross-sectional area of the psoas major muscle to the cross-sectional area of the lumbar 4/5 intervertebral discs (psoas index; PI) was calculated to correct for the difference in physique. Then, the presence or absence of correlations between the VAS and the Tönnis grade, the cartilage score, the BML score, the osteophyte score, the joint effusion score, the paralabral cyst score, and the psoas index was determined using Spearman rank correlation coefficient.

On further analysis, subjects were limited to end-stage osteoarthritis with Tönnis grade 3, and they were divided into 2 groups: the group with pain above the average VAS (P-group) and the group with pain below the average VAS (N-group). The Mann-Whitney *U* test was then used to test differences between the groups in the cartilage score, BML score, osteophyte score, joint effusion score, and paralabral cyst score. Similarly, Student *t* test was used to test whether there was a difference between the groups in the PI. Both the presence of a correlation and the presence or absence of a difference between groups were determined to be significant at $P < .05$. All statistical analyses were performed using the IBM SPSS Statistics version 26 (IBM, Armonk, NY, USA). Approval for this study was granted by the institutional review board of our university and subjects gave informed consent to participate.

Results

A total of 54 hips of 29 patients (8 males and 21 females) with an average age of 63 (42-83) years were evaluated. The average VAS of the subjects was 55.4 ± 39 mm, and all items (Tönnis grade, cartilage score, BML score, osteophyte score, joint effusion score, paralabral cyst score, and the PI) were significantly correlated with the VAS (Table 1). Strong correlations with a correlation coefficient of 0.7 or greater with the degree of pain were observed for the Tönnis grade, cartilage score at the centre to the medial part in the loading area, the BML score at the loading area of the femoral head, and the osteophyte score at the inferomedial site.

The number of the hip with Tönnis grade 3 was 38 cases (10 males and 28 females). The average VAS of only end-stage osteoarthritis with Tönnis grade 3 was 75.8 ± 26 mm. Those with a VAS of 75.8 mm or more were defined as the P-group (Painful group; 22 cases), and the others were defined as the N-group (Non-painful group; 16 cases). Three items were significantly different between the P-group and the N-group: the BML score in the central-inferior femoral head, the osteophyte score of the inferomedial femoral head, and the PI (Table 2).

Table 1. Correlation coefficient between each survey item and pain level.

	CORRELATION COEFFICIENT	*P* VALUE
Tönnis grade	0.7690	<.0001
Cartilage score central-medial	0.4565	.0005
Central-inferior	0.6749	<.0001
Central-central	0.7560	<.0001
Central-superior	0.7135	<.0001
Central-lateral	0.5906	<.0001
BML score central-medial (femur)	0.3846	.00410
Central-inferior (femur)	0.6188	<.0001
Central-central (femur)	0.6876	<.0001
Central-superior (femur)	0.7792	<.0001
Central-lateral (femur)	0.6234	<.0001
Central-inferior (acetabulum)	0.4007	.00267
Central-central (acetabulum)	0.4991	.00012
Central-superior (acetabulum)	0.5472	<.0001
Osteophyte score superolateral	0.5811	<.0001
Inferomedial	0.7098	<.0001
Anterior	0.4656	.0004
Posterior	0.5691	<.0001
Intra-articular	0.5995	<.0001
Effusion score	0.3259	.0161
Paralabral cyst score	0.6546	<.0001
Psoas Index (PI)	−0.5578	<.0001

Abbreviations: BML, bone marrow lesions; PI, Psoas Index.
Tönnis grade, cartilage score, BML score, osteophyte score, joint effusion score, paralabral cyst score, and the psoas index were significantly correlated with the pain measured using the visual analogue scale.

Discussion

In this study, imaging findings associated with pain in hip osteoarthritis were investigated. Cartilage damage near the loading area, the intensity changes of bone marrow on MRI (BMLs) near the loading area, and osteophytes that might be involved in instability of the hip joint showed strong correlations with the pain of hip osteoarthritis. Especially in the case of end-stage osteoarthritis only, osteophytes of the inferomedial femoral head, psoas major muscle atrophy, and BMLs in the central-inferior femoral head were associated with the degree of pain. This is the first report of such findings.

The diagnosis of osteoarthritis of the hip is often easy with only interviews, physical examination, and x-ray examination. However, even in hip osteoarthritis with similar x-ray findings, the complaints associated with pain vary widely. There are great individual differences not only in the location and nature

Table 2. Differences in imaging findings between painless and painful end-stage osteoarthritis of the hip.

	P-GROUP	N-GROUP	*P* VALUE
Cartilage score central-medial	1.23	0.75	.1786
Central-inferior	2.91	2.19	.0852
Central-central	3.55	3.44	.2878
Central-superior	3.59	3.50	.0903
Central-lateral	2.23	1.88	.3273
BML score central-medial (femur)	0.95	0.88	.7842
Central-inferior (femur)	1.36	0.63	.0213[a]
Central-central (femur)	2.05	1.50	.1274
Central-superior (femur)	2.18	1.75	.3758
Central-lateral (femur)	1.59	1.69	.8178
Central-inferior (acetabulum)	0.68	0.63	.6727
Central-central (acetabulum)	1.23	0.94	.3427
Central-superior (acetabulum)	1.45	0.75	.0551
Osteophyte score superolateral	2.36	2.19	.6903
Inferomedial	3.00	2.00	.0326[a]
Anterior	2.18	2.00	.6584
Posterior	2.32	1.69	.1419
Intra-articular	2.18	1.69	.2625
Effusion score	1.09	0.94	.4668
Paralabral cyst score	0.91	0.81	.3908
Psoas Index (PI)	0.30	0.37	.0292[a]

Abbreviations: BML, bone marrow lesions; PI, Psoas Index.
[a]There were 3 items showing significant differences between the painful group (P-group) and the non-painful group (N-group): the bone marrow lesion (BML) score in the central-inferior femoral head, the osteophyte score of the inferomedial femoral head, and the psoas index.

of the pain, but also in the degree of pain. In considering the best treatment for all while considering the complaints of these various symptoms, if the results of ordinary imaging findings can identify the cause of pain, more individualized treatment can be chosen.

The intensity changes of bone marrow on MRI as the finding associated with the pain of arthritis is called a BML, and it has been reported for a long time.[1-4] In our previous study, the intensity of the femoral head on MRI in all hip replacement cases was stronger than that of the healthy side.[10] These patients were scheduled to undergo total hip replacement with pain as their chief complaint; thus, these intensity changes in bone marrow on MRI were considered to represent 'bone pain'.

In the present study, the intensity changes on MRI were investigated in detail by site using the HOAMS system[1,8]; it was found that the intensity changes near the loading area had a strong correlation with the degree of pain. In other words, this study clarified the results of past research. In addition, focusing on the pain of end-stage hip osteoarthritis, which is the main target of surgical treatment, this study obtained new findings showing that when the intensity change reaches not only the loading part but also the central-inferior femoral head, it causes strong pain. Therefore, it is possible to predict that the pain is very strong or that the pain will be strong with such findings. Thus, early surgery can be recommended for such cases. Alternatively, in cases where conservative treatment must be continued, it can be determined that treatment should be focused on 'bone pain', such as the use of bisphosphonates.

Previous studies have reported that muscle weakness and muscle atrophy around the hip are also associated with the symptoms of hip osteoarthritis.[5-7] Our previous studies also showed a correlation, as with more pain of hip osteoarthritis, the greater is the atrophy of the psoas major muscle.[10] This correlation may indicate that disuse due to increased pain is associated with increased atrophy. However, the increased instability of the hip joint due to muscle atrophy may also be associated with the increased pain of hip osteoarthritis. Particularly in acetabular dysplasia cases, the original instability is the problem. In addition, if muscle weakness is caused by muscle atrophy, the instability of the hip joint is further exacerbated, and it may cause hip joint pain by itself. The increase in instability due to the decrease in muscle strength may lead to arthritis or acetabular labral injury, and such inflammation or damage also increases the pain of hip osteoarthritis. In the present study, the association between the pain of hip osteoarthritis and muscle atrophy by such mechanisms could be evaluated using the PI. The pain leads to a decrease in the activity of the hip joint, which causes further muscle atrophy. In patients with osteoarthritis suffering this vicious cycle, if the stability of the hip joint is increased by muscle strength training, such pain can be alleviated. Therefore, the results of this study show that the PI can also help determine conservative treatment strategies.

This study also provided new findings regarding osteophytes. It is generally believed that acetabular osteophytes above the femoral head provide stability to the hip joints. Particularly in dysplastic hip, the acetabular osteophytes above the femoral head reduce pain, similar to periacetabular osteotomy. In the present study, the presence of osteophytes at the inferomedial femoral head was shown to be associated with more pain. Both the acetabular osteophytes above the femoral head and the femoral head osteophytes at the inferomedial femoral head are thought to occur due to the instability of the hip joint. However, we believe that the acetabular osteophytes above the femoral head contribute to stability, whereas the femoral head osteophytes at the inferomedial femoral head do not contribute to stability, but rather serve as an indicator of instability. If there is muscle atrophy in addition to the femoral head osteophytes at the inferomedial femoral head, the wobbling of the femoral head inside and outside may increase. This phenomenon may cause impingement between the femoral head osteophytes at the inferomedial femoral head and the acetabulum, and then the intensity of the central-inferior femoral head on MRI may change.

The limitation of this study is that no intervention studies have been performed based on the above-mentioned hypothesis of the mechanism of pain in hip osteoarthritis. In the future, in conservative treatment for hip osteoarthritis, it will be necessary to clearly determine the target of pain treatment and to investigate changes in pain and changes in imaging findings. The biggest limitation of this study is the small sample size. Therefore, the effect of confounding factors could not be ruled out in this study. However, because this study was able to narrow down the pain-related items, it is likely that each facilities would investigate the relationship between these items and pain in the future with a very large sample size. The results of the present study not only show the first step towards studying new treatments for the pain of hip osteoarthritis, but they also provide findings from which the causes of pain can be inferred by focusing on specific imaging findings in daily practice.

Conclusions

The relationship between the degree of pain and imaging findings in end-stage hip osteoarthritis was investigated. Stronger pain was observed in the following patients: (1) patients in whom the intensity change of the bone marrow on MRI extends not only to the loading part, but also to the central-inferior part of the femoral head; (2) patients with greater psoas atrophy; and (3) patients with osteophytes at the inferomedial femoral head.

Author Contributions

HK: Conceptualization, Methodology, Investigation, Data Curation, Writing - Original Draft; SY: Resources, Data Curation, Supervision; NK: Resources, Data Curation, Supervision; HK: Conceptualization, Supervision; HT: Resources, Data Curation; TT: Investigation, Resources; NS: Investigation, Resources; KK: Resources, Data Curation; YO: Resources, Data Curation; MF: Resources, Data Curation; KS: Visualization, Investigation; TK: Visualization, Investigation; YI: Software, Validation; IN: Software, Validation; TM: Methodology, Formal analysis; NM: Supervision, Project administration; YS: Supervision, Project administration.

ORCID iDs

Hiroaki Kijima https://orcid.org/0000-0003-4939-9545
Takanori Miura https://orcid.org/0000-0002-1516-6105

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