Observational Study

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The comparison of measurement between ultrasound and computed tomography for abnormal degenerative facet joints

A STROBE-compliant article

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Abstract

Besides the study on examining facet joints of lumbar spine by ultrasound in normal population, there has not been any related report about examining normal facet joints of lumbar spine by ultrasound so far. This study was aimed to explore the feasibility of ultrasound assessment of lumber spine facet joints by comparing ultrasound measure values of normal and degenerative lumber spine facet joints, and by comparing measure values of ultrasound and computed tomography (CT) of degenerative lumber spine facet joints.

This study included 15 patients who had chronic low back pain because of degenerative change in lumbar vertebrae, and 19 volunteers who did not have low back pain or pain in the lower limb. The ultrasound measure values (height [H] and width [W]) of normal and degenerative lumber spine facet joints were compared. And the differentiation between measure values (H and W) of ultrasound and CT of degenerative lumber spine facet joints was also analyzed.

The ultrasound clearly showed abnormal facet joints lesion, which was characterized by hyperostosis on the edge of joints, bone destruction under joints, and thinner or thicker articular cartilage. There were significant differences between the ultrasound measure values of the normal (H: 1.26 ± 0.03 cm, W: 0.18 ± 0.01 cm) and abnormal facet joints (H: 1.43 ± 0.05 cm, W: 0.15 ± 0.02 cm) (all $P < .05$). However, there were no significant differences between the measure values of the ultrasound (H: 1.43 ± 0.17 cm, W: 0.15 ± 0.03 cm) and CT (H: 1.42 ± 0.16, W: 0.14 ± 0.03) of the degenerative lumber spine facet joints (all $P > .05$).

Ultrasound can clearly show the structure of facet joints of lumbar spine. It is precise and feasible to assess facet joints of lumbar spine by ultrasound. This study has important significance for the diagnosis of lumbar facet joint degeneration.

Abbreviations: H = height, MRI = magnetic resonance imaging, W = width.

Keywords: computed tomography, lumber spine facet joint, ultrasound

1. Introduction

Articular process joints of lumbar spine are also called facet joints of lumbar spine; its degeneration is one of the common reasons to cause low back pain.[1] In recent years, more and more research confirms that the degeneration of facet joints of lumber vertebrae plays a crucial role in low back pain.[2–4] Low back pain in 15% to 52% of the patients is closely correlated with lesion of facet joints in the lumbar spine.[5] At present, we can use X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) to diagnose degeneration of facet joints in the lumbar spine in imaging, especially CT. However, besides the study on examining facet joints of lumbar spine by ultrasound in normal population,[6] there has not been any related report about examining abnormal facet joints of lumbar spine by ultrasound so far. This study was aimed to evaluate the feasibility of a sonographic method used to evaluate the facet joints in the lumbar vertebrae by comparing ultrasound measure values of normal and degenerative lumber spine facet joints, and by comparing measure values of ultrasound and CT of degenerative lumber spine facet joints.

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2. Materials and methods

All study methods were approved by the Ethics Committee of Shengjing Hospital of China Medical University. All the subjects enrolled into the study gave written informed consent to participate.

2.1. Subjects

In this study, there were 20 volunteers who went to ultrasound department of our hospital for health examination, and 15 patients with chronic low back pain between January 2014 and December 2015. The inclusion criterion for volunteers was normal spinal column. The exclusion criteria for volunteers were histories of low back pain or pain in the lower limbs, treatment for osteoporosis, and lumber spine operation; and having congenital deformity of lumbar spine. However, the inclusion criterion for patients was chronic lumbar pain due to degenera-

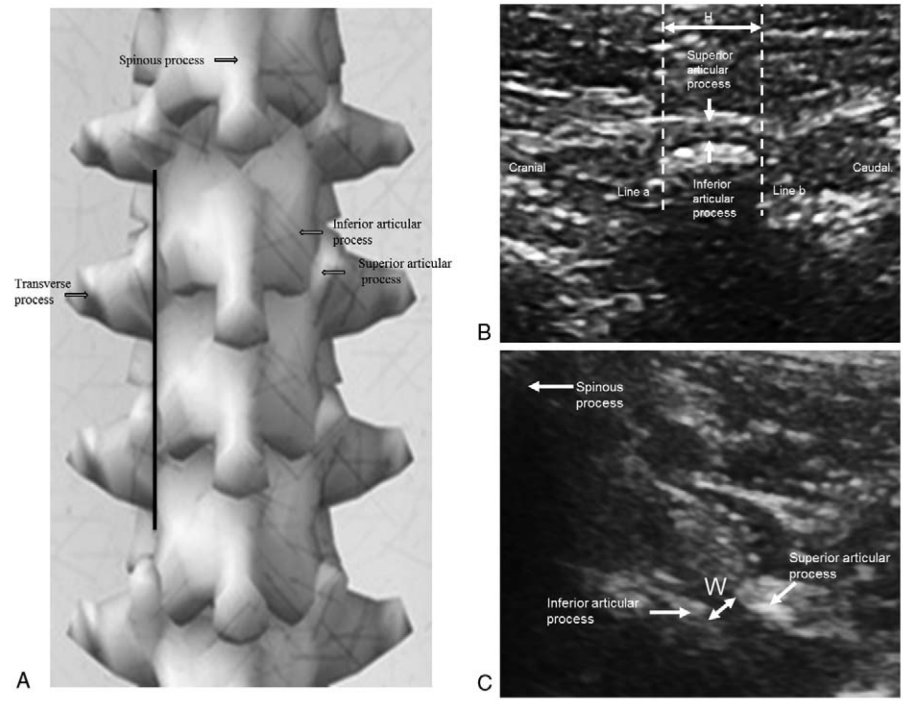

Figure 1. Sonogram of facet joints. (A) Schematic representation of the facet joint in sagittal plane. Black line: parasagittal line. (B) Facet joint of sonography in the parasagittal plane of the facet joint is the greatest dimension from the cranial (line a) to the caudal point (line b) of the hypoechogenic layer between the inferior and superior articular processes.(C) Facet joint of sonography in the transverse plan. W of the hypoechogenic layer is the greatest dimension perpendicular to the facet joints surfaces of inferior and superior articular processes. H = height, W = width.

tive change in lumbar vertebrae. The exclusion criteria for patients were lumbar spine tuberculosis or tumor; lumbar spondylolisthesis; and radiation pain in lower limbs.

2.2. Ultrasonography

In this study, the LOGIQ E9 (GE Healthcare, Zipf, Austria) Color Doppler Ultrasound Diagnostic instrument, equipped with a broadband convex array transducer working at 2.8 to 4.0 MHz and a broadband liner array transducer working at 11 to 15 MHz, was used. The volunteers and patients were in prone position. Scanning began in the sacrum, and moved headward. The vertebras from the sacrum on ultrasound were L5, L4, L3, L2, and L1, respectively. The transducer was placed in the midsagittal plane to visualize the spinous process of lumbar vertebra, and then moved to the paravertebral parasagittal direction from the midline position toward the transition between vertebral arch and the center of the joint (Fig. 1A). On the parasagittal plane, the transducer was rotated to transverse plane where laminae of vertebral arch, as well as superior and inferior articular processes were found. Then, the height (H) of facet joints was measured on the parasagittal plane (Fig. 1B) and the width (W) of facet joints was also measured on the transverse plane (Fig. 1C). Every H or W was measured 3 times. The H and W of facet joint of L1-S1 beside lumber spine were measured in each subject, and then were calculated to obtain mean values.

2.3. CT detection

All the subjects were examined using a 64-slice CT scanner (Sensation 64, Siemens Medical Solutions, Forchheim, Germany). Images were obtained with 1.25 mm collimation and a pitch of 3 (0.75 mm/rotation), at 250 mA and under 120 kV. The subjects were in supine position to examine L1-S1. We used 3D volume fusion tool for CT image progressing. The H of facet joints on parasagittal plane and the W of facet joints on transverse section were measured. The H was defined as the greatest distance from the cranial point to the caudal point between the superior and inferior articular process (Fig. 2A). Similarly, the W referred to the greatest distance perpendicular to the posterior parts of the joint space in the cross section (Fig. 2B).

2.4. Statistical analysis

Ultrasound and CT measurements were respectively performed by ultrasound doctor (YH) and orthopedist (DL), both with more than 10 years of experience; and they were blind to this study. The intraobserver repeatability of measurements was assessed by intraclass correlation coefficients with 95% confidence intervals (CIs) about 10 subjects. Analysis of the difference between the observational variability was performed according to the technique of Bland and Altman.[7]

Statistical treatment was performed using SPSS 16.0 software (SPSS Inc., Chicago). We calculated mean values of ultrasound and CT of every facet joints of L1-S1, respectively. The H and W values were expressed as mean value ± standard deviation (SD) ($\overline{X} \pm s$). The ultrasound measure values (H and W) were of normal and degenerative lumber spine facet joints were compared, and the differentiation between measure values (H and W) of ultrasound and CT for degenerative lumber spine facet joints was also analyzed, using Student *t* test.

3. Results

3.1. The analysis of interrater agreement

The results of the intraclass correlation coefficients for the intraobserver reproducibility of the sonography and CT measure-

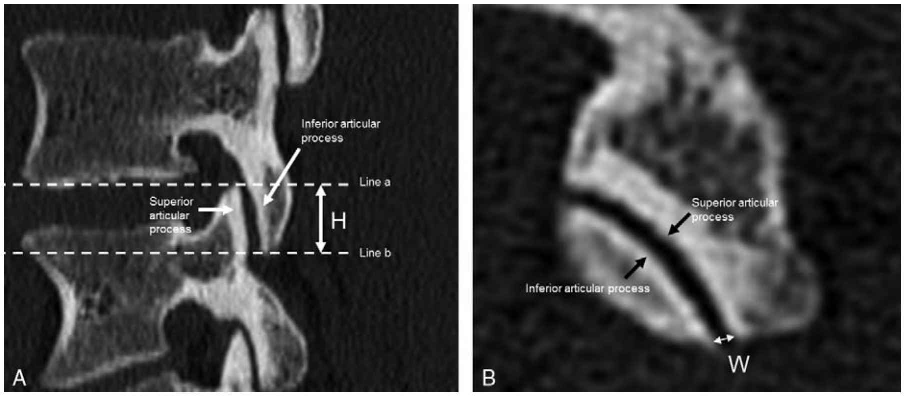

Figure 2. CT image of facet joints. (A) Facet joint of the CT imaging in the parasagittal plane. Parameter of H of the facet joint was defined as the greatest dimension from the cranial (line a) to the caudal point (line b) between the inferior and superior articular processes. (B) Facet joint of CT imaging in the transverse plan. W of the facet joint was the greatest dimension perpendicular to the posterior portions of the joint surface.

Table 1

Intraclass correlation coefficients of ultrasound and CT parameters in different facet joints.

Measurements	Intraclass coefficient	95% confidence interval	SD of the differences	*P*
Ultrasound parameters, cm				
H of the facet joint	0.76	0.70–0.88	0.07	<.05
W of the facet joint	0.73	0.70–0.82	0.13	<.05
CT parameters, cm				
H of the facet joint	0.71	0.65–0.78	0.11	<.05
W of the facet joint	0.62	0.64–0.81	0.15	<.05

CT = computed tomography, H = height, SD = standard deviation, W = width.

ments are summarized in Table 1. In all cases, there was no significant bias ($P > .05$) because the difference between measurements remained stable and the mean and SD of differences appeared constant throughout the range of measurements for all comparisons.

3.2. Ultrasound and CT imaging of facet joints of lumber spine

For normal facet joints of lumbar vertebrae, articular surface of superior and inferior articular process was smooth and high echoic with clear border. Articular cartilage was clear, low-echoic, and located between articular processes (Figs. 3 and 4). However, for abnormal facet joints of lumbar vertebrae, joint space narrowed or widened, articular surface was rough or uneven, and there was bone destruction under joints. Also, there was bone hyperplasia, even osteophytes, and other facet joints' degeneration on the edge of facet joints (Figs. 5 and 6).

3.3. Comparison of sonography outcomes of normal and abnormal facet joints of lumbar spine

One of the 20 volunteers was excluded from this study because extra fat and thick muscle in his back interfered with the sonography examination. Finally, 19 volunteers were enrolled in this study. Therefore, a total of 190 facet joints were evaluated by sonography, because 5 pairs of facet joints (L1-S1) were examined in each volunteer. In the 19 volunteers, ultrasound-measured H of the left facet joints of L1-S1 is 1.30 ± 0.03, 1.31 ± 0.03, 1.24 ± 0.02, 1.19 ± 0.02, and 1.24 ± 0.02 cm, respectively, and the right H is 1.32 ± 0.04, 1.31 ± 0.05, 1.24 ± 0.02, 1.18 ± 0.03, and 1.24 ± 0.02 cm, respectively. There was no statistical difference between the H of left and right facet joints (L1-S1) (all $P > .05$). In the 19 volunteers, ultrasound-measured W of the left facet joints of L1-S1 is 0.18 ± 0.01, 0.18 ± 0.01, 0.18 ± 0.01,

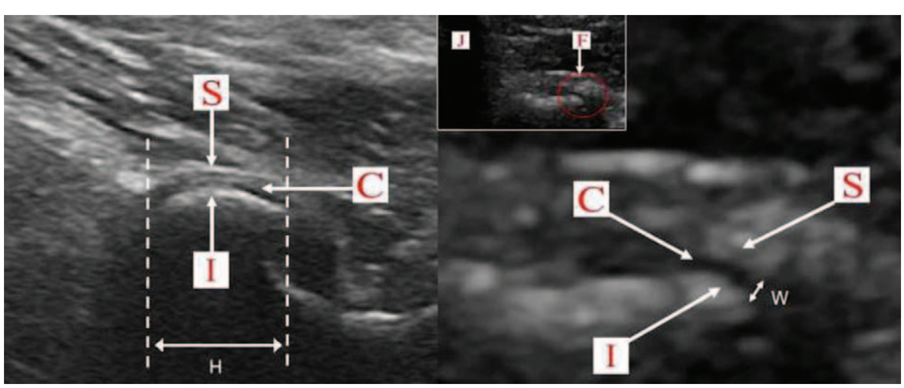

Figure 3. Sonogram of normal facet joints. The left sonogram shows the parasagittal plane of the normal facet joints. Notes: In the left sonogram, S indicates superior articular process, I indicates inferior articular process, and C indicates articular cartilage. The articular surface of the superior and inferior articular processes is smooth, arcuate, and high echoic. Articular cartilage is clear and low echoic, and is located between articular processes. Right sonogram shows the transverse section of the normal facet joints. Notes: In the right sonogram, J indicates spinous process of lumbar vertebrae and F indicates facet joint. There is a low-echoic fissure on the irregular, curved, and high-echoic stripe, which is articular cartilage.

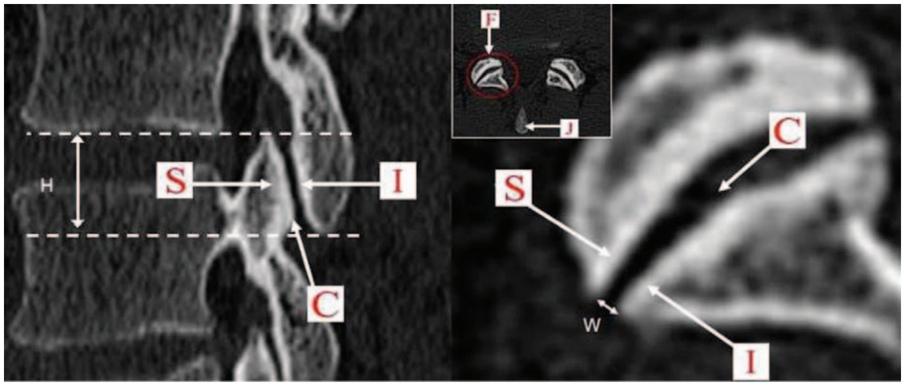

Figure 4. CT image of normal facet joints. The left is the CT image of the parasagittal plane of the normal facet joints. The right is the CT image of the transverse section of the normal facet joints. Notes: S indicates superior articular process, I indicates inferior articular process, C indicates articular cartilage, J indicates spinous process of lumbar vertebrae, and F indicates facet joint. The articular surface of superior and inferior articular process is smooth, regular, and high-density. The low-density fissure between articular processes is articular cartilage.

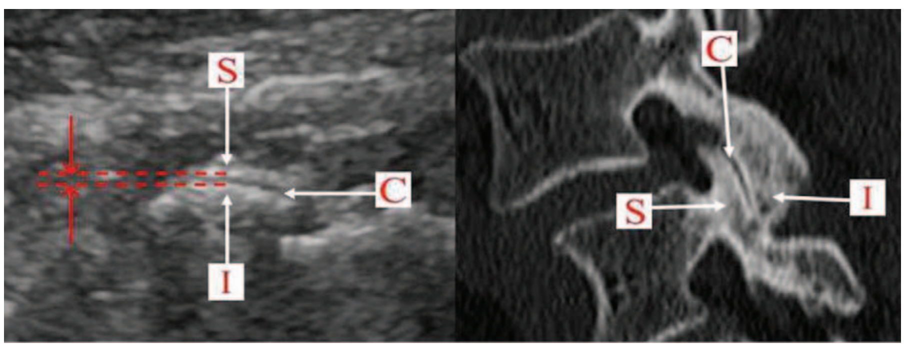

Figure 5. Pictures of abnormal facet joint on the parasagittal plane. Notes: In the left sonogram, S indicates superior articular process, I indicates inferior articular process, and C indicates articular cartilage. The articular cartilage turns thinner obviously and joint space turns narrow. The right picture is the corresponding CT image.

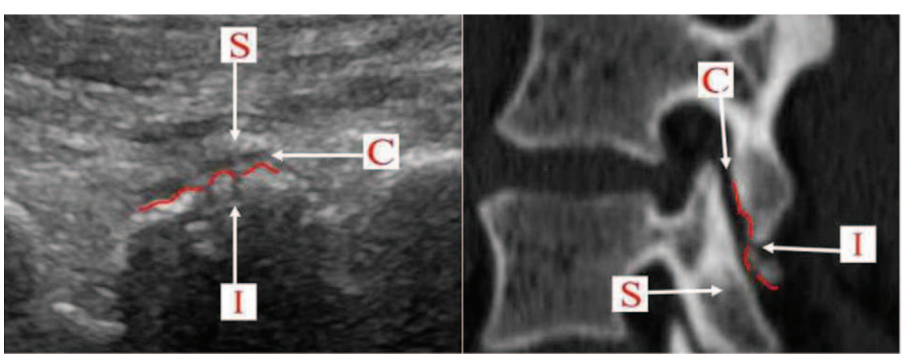

Figure 6. Pictures of abnormal facet joint on the parasagittal plane. Notes: In the left sonogram, S indicates superior articular process, I indicates inferior articular process, and C indicates articular cartilage. The bone of the inferior articular process is destroyed, so the continuity of articular surface is broken. The right picture is the corresponding CT image.

0.19 ± 0.02, and 0.17 ± 0.01 cm, respectively, and the right W is 0.17 ± 0.01, 0.18 ± 0.02, 0.18 ± 0.01, 0.18 ± 0.01, and 0.18 ± 0.01 cm, respectively. There was no statistical difference between the W of left and right facet joints (L1-S1) (all $P > .05$).

A total of 15 patients were enrolled in this study. All the 15 patients had a medical history of low back pain. Among the 15 patients, 2 had prolapse of lumbar intervertebral disc and 1 had lumbar spinal stenosis. Therefore, a total of 150 facet joints were

Table 2

Ultrasound-measured H and W values of facet joints of lumber spine in volunteers and patients.

Groups	Joint number	Joint H	Joint W
Volunteers	190	1.26±0.03	0.18±0.01
Patients	150	1.43±0.05	0.15±0.02
t Value		2.626	2.264
P value		.015	.045

H = height, W = width.

evaluated. Two groups' independent samples *t* test displayed that there were significant differences between ultrasound-measured H and W values of both normal and abnormal facet joints of lumber spine (all $P<.05$) (Table 2).

3.4. Comparison of outcomes of sonography and CT in abnormal facet joints of lumber vertebrae

There were no significant differences between measure values of ultrasound (H: 1.43±0.17, W: 0.15±0.03) and CT (H: 1.42±0.16, W: 0.14±0.03) for abnormal facet joints of lumber vertebrae ($P=.407$ and $P=.061$, respectively).

4. Discussion

The incidence of low back pain is increasing year by year, and lumbar facet joint degeneration is one of the common reasons to cause low back pain.[8,9] Therefore, it is significant to assess facet joints of lumbar spine for diagnosis and treatment of low back pain. Facet joint of lumbar spine is also called articular process joint or vertebral arch joint. It is made of superior and inferior articular processes, attached to each other. Hyaline cartilage is located between articular processes and covers the articular surface. Lumbar facet joint degeneration is mainly caused by the changes in articular cartilage, synovial membrane, joint capsule, and bone of articular process.[10]

Currently, the imaging-diagnostic methods for lumbar facet joint degeneration include X-ray, CT, and MRI. However, CT is the most efficient method to examine facet joints of lumbar vertebrae compared with MRI and X-ray. CT scanning is able to show the shape, structure, and degeneration degree of facet joints of lumbar spine clearly with a high discovery rate of early or mild degeneration and very precise spatial resolution.[11,12] As a result, we often use CT as a gold standard to confirm the precision of ultrasound examination for lumbar facet joints. Although it is the most efficient method to detect facet joints of lumbar vertebrae, CT still has some disadvantages. For example, CT cannot show the change of articular cartilage in the early stage of facet joints' degeneration. Also, the patients may have side effect and complications because they have to receive more radiation dose. Therefore, this may be very harmful to the patients who require repeated CT detections.[13,14]

Compared with X-ray, CT, and MRI, ultrasound has many advantages; first, sonography is easy, fast, and noninvasive. Second, it is convenient for dynamic observation and follow-up visit. Third, its price is lower compared with CT and MRI. Since sonography does not induce radiation injury, patients may be examined repeatedly and multidimensionally.[15–17] Ultrasound as a guidance tool has been widely used on the puncture treatment of facet joints of lumber spine. It has been reported that ultrasound-guided radiofrequency ablation of lumbar sensory nerves has better therapeutic effects, safety, and little trauma for lumbar facet joint syndrome.[18] Moreover, Wen et al[19] used ultrasound to detect and locate facet joints of lumber spine precisely to provide technology support for ultrasound-guided block of facet joints of lumber spine. As a consequence, ultrasound has vast potential for future development on the assessment and diagnosis of facet joints of lumber vertebrae, and it will provide new method and basis for clinical diagnosis.

However, there are no specific outcomes on ultrasound imaging of facet joints of lumber spine. Our study displayed that on the parasagittal planes of back, ultrasound could clearly show the high-echo superior and inferior articular processes and the low-echo articular cartilage between them. When the transducer was rotated, on transverse plane, we could see a low-echo fissure on a stripe of irregular, curved, and high-echo image, that is low-echo articular cartilage. Therefore, the H of facet joint is the H of articular cartilage and the W of facet joint is the W of articular cartilage. We use the H and the W of facet joints to describe and evaluate the condition and degeneration degree of facet joints.[6]

The directivity of facet joints of lumber vertebrae varies according to different ages. In fetal and infant period, the facet direction of facet joints of lumber spine is nearly coronal plane. Then as the lateral edge of facet joints turns to sagittal plane little by little, the facet turns to curve and is mainly sagittal. That is to say, the articular facet of superior articular process is toward back medial space and the articular facet of inferior articular process is toward forward lateral space. The angle between horizontal plane and adult's facet of small joints of lumber spine is 90°. And the angle between medial sagittal plane and adult's facet of small joints of lumber spine is 25.89° to 50.3°.[20] The facets' directions vary in different segments of the lumber spine. The trend of the facets' directions is that from top to bottom, the articular facets of articular processes turn from coronal plane to sagittal plane with a right angle between it and the horizontal plane. The angle between articular process of T12-L2 and vertebra is 26° to 34° and the angle between articular process of L3-L5 and vertebra is almost 40° to 56°.[20] Therefore during the ultrasound scanning, the direction of transducer should vary according to different segments of facet joints of lumber spine. From the data of volunteer group, we could see that the Hs of facet joints of L4-L5 were relatively short and the Hs of facet joints of L1-L2 and L2-L3 were relatively long, but their Ws had nearly no difference.

Lumber facet joint degeneration is most common in L4-L5 and the degeneration is mainly caused by the changes in articular cartilage, synovial membrane, articular capsule, and articular process bone.[10,14] The study performed by Suthar et al[14] shows that a common degenerative change of intervertebral discs is disc desiccation. That is because the glycosaminoglycans in the nucleus pulposus is replaced by the fibrocartilage which reduces disc H due to reduction in the volume of nucleus pulposus. The results suggested that lumbar disc degeneration contributed to low back pain, and the mechanisms of lumber disc degeneration would promote the development of new therapies for low back pain caused by lumbar disc degeneration.

5. Limitation

However, ultrasound does not have the obvious advantage compared with CT and other examinations for obese patients because it cannot clearly show articular processes.

6. Conclusion

Ultrasound can clearly show the structure of facet joints of lumbar spine, so it is precise and feasible to assess facet joints of lumbar spine by ultrasound; and it is meaningful to diagnose degeneration of facet joints of lumbar spine by ultrasound. However, ultrasound does not have the obvious advantage compared with CT and other examinations for obese patients because it cannot clearly show articular processes.

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