Clinic research between vertebral endplate morphology and lumbar disc herniation☆

Gu Hong-sheng, Zhou Wen-yu, Li Zhen-yu

Abstract

BACKGROUND: Studies demonstrated that vertebral endplate can be remodeled during intervertebral disc degeneration. However, the relationship between morphology of the vertebral endplate and intervertebral disc degeneration remains poorly understood.

OBJECTIVE: To explore the relationship between the morphology of the vertebral endplate and the lumbar disc herniation.

METHODS: Forty cases without previous spine disorder and sixty-two cases symptomatic lumbar disc herinations lumbar vertebral were scanned by using spiral CT. Scan range was from superior L_4 to superior S_2. Scan protocols as below: 140 kV, 345 mAs, FOV 160 mm, layer of thick 1 mm, pitch 1.0. Original images were carried through three-dimensional reconstructions using O_2 image work station, W300, C80, ZOOM=1.5, Expand 1. Intervertebral disc maximum anteroposterior, transverse diameter, circumference, area and shape were measured based on curve planar reconstruction.

RESULTS AND CONCLUSION: Endplate shape was strongly related to disc herniation (all the *P* value < 0.01). Endplate area was a less significant factor $L_{4/5}$ in men and L_5/S_1 in men and females (P < 0.05). The shape of the intervertebral body endplate margin is an important factor contributing to the development of disc herniation at $L_{4/5}$ and L_5/S_1.

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INTRODUCTION

Intervertebral disc plays an important role in bearing the weight of body. Commonly, almost all the spinal compression load and 45% torsion loads were assumed to the intervertebral discs. Vertebral endplate is very important for the biodynamic transmission and stress redistribution of intervertebral disc. Degenerative discs degeneration frequently accompanied by the narrow of intervertebral space and sclerosis of endplate and formation of osteophyte. According to our knowledge, regretfully, much published research had mainly focused on the changes of height, maximum anteroposterior, diameter, transverse diameter, mechanics and biochemics[1-2]. However, the circumference, area and shape of endplate were rarely investigated. The current study investigated interveterbral disc morphology and relationship with intervertebral disc herniation of low back using spiral computed tomography (CT) with three-dimensional (3-D) reconstruction techniques.

MATERIALS AND METHODS

Design

A case control study.

Subjects

The subjects included 3 groups. Group 1 was defined as normal control including 40 cases of normal without lumbar and leg pain. The normal control initially performed CT examination of pelvis or abdomen for suspected pelvic tumors or regular health examination, including 20 males and 20 females with the age from 20 to 48 years (mean 32.9 years). Group Ⅱ and Ⅲ were generally defined as intervertebral herniation with 62 cases involved, including 35 males and 27 females. Group 2 was claimed intervertebral herniation of $L_{4/5}$ including 36 cases with 20 males and 16 females, aged 21 to 45 years (mean 28.3 years). Group 3 was assumed to intervertebral herniation of L_5/S_1, including 26 cases with 15 males and 11 females, aged 28 to 41 years (mean 29.8 years). Patients suffered from intervertebral herniation of $L_{4/5}$ and L_5/S_1, or accompanied by osteoarthritis were excluded. According to *Administrative Regulations on Medical Institution*[3], informed consent was obtained from each participant.

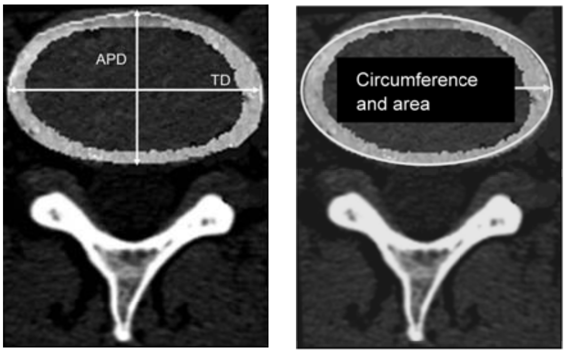
Methods

Spiral CT examination

All the CT examinations were performed with a spiral CT machine (Twin Flash, Elscint Company). The scan ranged from inferior L_4 to superior S_2 with supine position. The scan protocols were as follows: 140 kV, 345 mAs, a field of view of 160 mm, a section thickness of 1 mm and a pitch of 1.0. The original images were post processed by multiple planar reconstructions (MPR) with a window width of 300, a window centre of 80 and gapless on the O_2 workstation. After MPR, curve planar reconstruction was performed along inferior L_4, superior L_5, inferior L_5 and superior S_1. The following parameters were measured to investigate the morphology of endplate.

Parameter measurement

The anteroposterior diameter (APD) and transverse diameter (TD) of the endplate were directly measured on the original CT images. The circumference and area of the endplate were measured with freehand technique of O_2 software packages. Because the accuracy of measurement endplate was slightly impaired by the co-existent pedicle of vertebral, we measured the circumference and area of superior L_4 and L_5 respectively which expected to be more accurate substitutions for the circumference and area of invtervertebral discs of $L_{4/5}$ and L_5/S_1 (Figure 1).



a: Anteroposterior diameter (APD) and transverse diameter (TD)　b: Circumference and area

Figure 1　Measurement of shape and area of vertebral endplate

Endplate morphology

The lumbar endplate morphology was reflected by a variable which was directly calculated from the following formula: The lumbar endplate morphology = APD/TD.

Main outcome measures

①APD and TD of endplate. ②Circumference, area and morphology of the endplate. ③Pearson correlation.

Statistics analysis

All the measurements were implemented by a radiologist and an orthopedist simultaneously to avoid the possible error resulted from subjective measurement. The ultimate data were obtained after the average from two doctors and the analysis of Pearson correlation. SPSS (10.0) was used for all statistic analyses. A *P* value of < 0.05 was considered statistically significant.

RESULTS

APD and TD of endplate

The APD and TD, especially APD, were significantly longer in intervetbral disc herniation than that in normal control. Compared with normal control, the APD of inferior L_4 and superior L_5 in group Ⅱ were significantly different both in males and females ($P < 0.01$). There was a significant difference in the APD of superior L_5 and inferior S_1 between group 3 and normal control both in males and females ($P < 0.01$). However, the TD was not significantly different between group Ⅱ and group Ⅲ ($P > 0.05$; Table 1).

Circumference, area and morphology of the endplate

Detail circumference, area and morphology of the endplate were shown in Table 2. The circumference of endplate of male in group Ⅱ and group Ⅲ was significantly different from that in normal control ($P < 0.05$). However, in females, the circumference of endplate was found significantly different merely in group 3. There was no significant difference in the area of endplate between normal control and intervertebral disc herniation. The morphology of endplate was significantly different between normal control and intervertebral disc herniation of female and male ($P < 0.01$).

According to Pearson correlation analysis, the measured TD of inferior L_4 and L_5 were randomly selected (Table 3). The coefficient in correlation analysis the measurement between the radiologist and the orthopedic doctor were 0.963 and 0.975 respectively with statistic significance (group a: t=11.95, $P < 0.01$; group b: t=12.60, $P < 0.01$).

Table 1　The anteroposterior diameter (APD) and transverse diamete (TD) of vertebral endplate　($\bar{x}\pm s$)

Position	Gender	APD		
		Ⅰ	Ⅱ	Ⅲ
L_4 inferior	Male	36.1±3.1	40.6±3.5[a]	36.3±3.1
	Female	31.3±2.1	35.2±3.2[a]	31.4±3.0
L_5 superior	Male	35.8±2.9	40.4±3.4[a]	36.2±3.2
	Female	32.3±2.2	35.9±2.9[a]	31.2±3.1
L_5 inferior	Male	35.4±2.8	35.6±3.0	40.2±3.1[a]
	Female	32.1±2.2	32.1±2.3	36.4±2.9[a]
S_1 superior	Male	32.9±2.3	33.1±3.0	39.3±2.8[a]
	Female	29.5±1.8	30.1±2.0	36.7±3.1[a]
Position	**Gender**	**TD**		
		Ⅰ	Ⅱ	Ⅲ
L_4 inferior	Male	53.3±3.9	54.8±4.3	53.1±3.2
	Female	47.8±3.6	48.8±4.5	47.1±4.1
L_5 superior	Male	53.4±4.0	54.6±4.2	53.5±4.1
	Female	47.9±3.6	49.8±4.8	47.7±3.9
L_5 inferior	Male	52.1±3.7	51.8±4.1	55.1±4.8
	Female	47.0±3.5	47.1±3.7	49.2±4.3
S_1 superior	Male	52.8±3.8	51.2±3.7	53.8±4.3
	Female	47.2±3.5	47.5±4.0	49.6±4.2

[a]$P < 0.01$, *vs*. normal control group

Table 2　The area, circumference and shape of vertebral endplate　($\bar{x}\pm s$, mm)

Item	Position	Male		
		Normal	Herniated	*t*
Circumference (cm)	$L_{4/5}$	15.2±2.0	16.8±2.1	2.467[a]
	L_5/S_1	15.0±1.8	16.3±1.9	2.049[a]
Area (cm^2)	$L_{4/5}$	14.3±1.9	15.7±2.3	2.099[a]
	L_5/S_1	14.5±2.1	15.9±2.3	2.233[a]
Shape	$L_{4/5}$	0.68±0.04	0.74±0.06	3.723[b]
	L_5/S_1	0.67±0.04	0.73±0.06	3.824[b]
Item	**Position**	**Male**		
		Normal	Herniated	*t*
Circumference (cm)	$L_{4/5}$	13.8±1.5	14.7±1.5	1.789
	L_5/S_1	14.0±1.8	15.0±1.6	1.592
Area (cm^2)	$L_{4/5}$	12.1±1.4	13.1±1.6	1.969
	L_5/S_1	11.7±1.3	12.8±1.4	2.146[a]
Shape	$L_{4/5}$	0.65±0.03	0.72±0.05	4.933[b]
	L_5/S_1	0.67±0.04	0.74±0.05	3.741[b]

[a]$P < 0.05$, [b]$P < 0.01$

Table 3　Pearson correlation coefficient　($\bar{x}\pm s$)

Operator	Group A (*n*=20)	Group B (*n*=11)
Orthopedist	53.7±4.0	49.9±3.6
Radiologist	55.2±4.4	48.7±3.9
r	0.963[a]	0.975[a]

Group A: male transverse diameter of L_4 inferior vertebral endplate in group
Group B: female transverse diameter of L_5 inferior vertebral endplate in grou
Ⅲ; [a]$P < 0.01$

DISCUSSION

Clinical relevance of endplate morphology

Lumbar intervertebral disc herniation is one of the most commonly diseases of low back in clinically, also the most frequent cause of low back pain. Intervertebral disc of $L_{4/5}$ and L_5/S_1 are the most frequently herniated discs. At present, intervertebral disc herniation was considered resulted from the degeneration and heredity of discs and rotational and axial flexion compression which act on the anulus fibrous. However, these hypotheses could not satisfactorily interpret the pathological basis of herniation in many non-manual workers and large-body-size people. Previously published research on the disc focused on the nucleus pulposus and the anulus fibrosus, whereas, the studies on the endplate particularly laid emphasis on its biological stress and nutrition. The morphology of disc was rarely investigated. The exact relationship between lumbar disc morphology and intertebral disc herniation is still not clear[4].

Heliovaara[5] suggested that only body height was related to the intervertebral disc herniation. Adams *et al*[6] found that slight damage to the endplate would result in the progressive destruction of contiguous discs. Lu *et al*[7] suggested, in a study on spinal loading with 3-d finite element model to separate simulate the disc height of 8 mm, 10 mm and 12 mm, that the height of disc had significant effects on axial shift of verterbral body, intervertebral disc posterior-lateral protrusion and tension of outer anulus fibrosus, but slight on inner pressure of disc and transmission of endplate pressure. However, these studies prophesized that intervertebral disc belong to the linear mechanic model and morphology and area of endplate had not been considered, therefore, were not satisfactory to interpret the full stress-bearing mechanism of lumbar. Zhou *et al*[8] suggested the width and depth of vertebral Lamina of L_3 to L_5 increased gradually and the morphology of endplate was direct influential on the height of discs. In the present study, we had measured the circulatory and area of L_4 with the result of 14.1 cm and 1 492 mm^2, respectively, whereas not measured that of L_3, L_5 and superior S_1 endplate.

The endplate morphology of low lumbar gradually transformed from heart-shaped to ovoid. Whether this kind of obviously morphological changes could affect the biomechanic transmission of disc and whether the endplate morphology is different in intervertebral disc herniation from normal are unclear yet. These problems had been resolved in this study. In addition, the research on the morphology of Lamina of lumbar vertebra is facilitating to rational intervertebral confluence with implanted bone and the design of artificial intervertebral disc prosthesis domestically.

Evaluation of methods for studying endplate morphology

The endplate morphology has been previously investigated by the means of autopsy specimens, X-ray plain film and conventional CT. Nevertheless, the autopsy specimens are hardly available. X-ray plain film merely provided two-dimension images and could not display endplate in sectional plane. The 3-d reconstruction in conventional CT is not satisfactory for the insufficiency of equipment and undesired cooperation of patients. Hall *et al*[2] tried to establish a geometry model of low lumbar endplate with CT which was difficult to apply in practice. On magnetic resonance imaging, the borderline of endplate is hart to define. Spiral CT has been established is superior to Magnetic resonance imaging in the discrimination of bone and the required imaging time. Therefore, in our opinion, spiral CT is deserved an alternative excellent method to explore the disc[9-10].

Image quality of spiral CT and its clinical significance

Endplate is ovoid shape. It is thicker peripherally and relatively thinner centrally, and the anterior thickness is larger than the posterior thickness, but the bilateral thickness is essentially similar. The 3-d reconstruction in conventional CT is not satisfactory for the insufficiency of equipment and undesired cooperation of patients. With the development of spiral CT and popular application of computer, 3-d technique experienced a marked advance. The application of spiral CT had quickly extended from complex anatomic locations such as craniofacial region, thorax and abdomen to bone joints in extremities and spine. In the 3-d reconstruction of spiral CT, a thinner slice thickness, larger pitcher and lesser reconstruction gap (50 percentage of slice thickness) are appropriate. Generally, a slice thickness no more than 3 mm, a table feed no more than 5mm and a reconstruction thickness no more than 2 mm are recommended for smoothing the cortical bone and without step-like artifacts on MPR images. In addition, image quality is closely related to the window width and widow centre, correctly selection, coordinating and matching are required for the images with high contrast resolution and good quality. In current study, a thickness of 1 mm, a window with of 300 and a window centre of 80 were used for the perfect images. As the disc height is larger in central than that in peripheral. The endplate morphology could not be precisely described on conventional CT due to the parallelized scan image plain to intervertebral space. However, in spiral CT, volume rendering and curve planar cut could be applied, then, make the measurement of morphology more simply and accurately. In addition, another superiority of cure planar reconstruction is that the reconstructed images could be arbitrarily cut, therefore, the scan plane is unnecessary to parallel to the intervertebral space. The scan thus is more easily to perform and the accuracy of examination is higher[11], especially in females with larger lumbar-sacral angle between L_5 and S_1.

APD and TD of endplate

In our study, the APD and TD were longer in intervertevral disc herniation than that in normal. Especially, there was significantly difference in APD between intervertevral disc herniation and normal control. It suggested that anterior-posterior diameter was the main change in intervertevral disc herniation, consistent with the disc herniation direction seen in clinical.

Circumference and area of endplate

Normally, the endplate and anulus fibrosus are enclosed together by nucleus pulposus, thus, the disc forms similar to a tightly sealed self-limiting container to buffer outer forces. From the research emerged, most scholars conceded that the lumbar endplate morphology transformed from heart-shaped superiorly to ovoid inferiorly and directly affected the height of discs. Harrington *et al*[12] had found, the multivariates correlation and regression analysis of CT scan that intervertebral disc herniation in $L_{4/5}$ and L_5/S_1 is closely related with the morphology of endplate margin, while the area of endplate affected intervertebral disc hernaiton in male. Our data suggested that the endplate of $L_{4/5}$ and L_5/S_1 changed from ovoid to round gradually, which indicating increased index of vertebral lamina in intervertebral disc hernaiton. The intervertebral disc hernaiton correlated with endplate circulatory in males, whereas the correlation was found merely in L_5/S_1 in female intervertebral disc hernaiton, which suspect to result from the larger lumbar-sacral angel in females.

Endplate morphology and inner pressure of anulus fibrosus

Endplate, as a flat disciform structure, is thicker peripherally and relatively thinner centrally. The anterior thickness of endplate is larger than the posterior thickness, while, the bilateral thickness is basically equal. The biomechanics research indicated that increased tension of anulus fibrosus resulted in 1aceration of anulus fibrosus, furthermore, led to intervertbral disc herniation. Water, collagen and proteoglycan are the main components of discs. The water fraction of discs varies with aging from 70% to 90% individually. Whereby, intervertebral disc could be considered as a short cylinder fully filled with liquid. Theoretically, the inner mural pressure of annulus fibrosus could be obtained from Laplace formula as follows: inner mural pressure=transmission pressure×radius/mural thickness. According to Laplace law, inner pressure of lateral intervertebral disc was highest, which suffered most possible to protrude[13]. However, in clinic, the posterior-lateral intervertebral disc herniation is most common. The estimated reasons include as follows: lateral intervertebral disc herniation has not identified for lack of symptom related to neuropathy. Posterior-lateral anulus fibrosus is relative thinner. The posterior-lateral ligament is easily stained for flexion-extension, which is the main physical activity in normal people.

Our results showed that morphological index increased in intervertebral disc herniation, whereby, suggesting endplate morphology was an important factor for intervertebral disc herniation. Nevertheless, posterior-lateral lumbar disc herniation occurred frequently not only for its morphological changes, but the larger stress lumbar endured and the direction of outer forces. Thereby, the stress and vertebral lamina morphology are possible two very important factors for the lumbar intervertebral disc herniation[14].

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椎体终板形态与腰椎间盘突出关系的临床研究☆

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摘要

背景：有研究报道，在间盘退变的过程中，可造成椎体终板的重塑。目前终板形态和椎间盘退变的关系仍不非常清楚。

目的：观察分析椎体终板形态与腰椎间盘突出症的之间的关系。

方法：纳入 40 例无腰椎疾病的正常人和 62 例腰椎间盘突出症患者，进行螺旋 CT 扫描，扫描范围从 L_4 到 S_2，扫描条件：140 kV，345 mA，FOV160 mm，层厚 1 mm，间距 1.0。原始图像通过 O2 的三维重建图像工作站进行三维重建，W300, C80, ZOOM=1.5，Expand1。在平面重建术(CPR)基础上测量椎间盘最大前后，横径，圆形，面积和形状。

结果与结论：终板形态和椎间盘突出症密切相关(P 均< 0.01)。终板面积和男性 $L_{4/5}$、男性和女性的 L_5/S_1 椎间盘突出关联差异无显著性意义($P < 0.05$)。提示椎体终板的边缘形状是腰椎的椎间盘突出症($L_{4/5}$、L_5/S_1)进展的重要因素之一。

关键词：椎体终板;椎间盘;椎间盘突出症;螺旋 CT

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