High-intensity zone (HIZ) of lumbar intervertebral disc on T2-weighted magnetic resonance images: spatial distribution, and correlation of distribution with low back pain (LBP)

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Abstract

Objectives To analyze the three-dimensional distribution of high-intensity zone (HIZ) in lumbar disks and to assess the correlation between low back pain (LBP) and spatial distribution of HIZs.

Methods Clinical records and lumbar MRIs of 623 patients (337 males and 286 females, age 50.10 ± 15.38 years) were selected and reviewed. Baseline characteristics and 3D localization were performed and recorded by two radiologists in a blind fashion.

Results Among the 623 patients, 200 exhibited an HIZ in at least one disk. HIZs were more frequently seen in the inferior part of annulus fibrosus (superior–middle–inferior ratio 39:59:140, $P < 0.001$). One hundred and eighty-one HIZs (76.1%) occurred at L4/5 and/or L5/S1. The prevalence of multi-segmental HIZ was 16.5%. Among the 33 patients with multi-segmental HIZs, 24 exhibited HIZs in adjacent disks. The LBP rate of HIZ patients was significantly higher than that of patients who exhibited no HIZ (57.5 vs. 47.8%, $P < 0.05$). There was no evidence for a correlation between LBP and spatial distribution of HIZ in disk ($P > 0.05$). The incidence of LBP was slightly higher when the HIZ disk level was lower or when there were

HIZs exhibited in more disks; however, the difference was statistically insignificant ($P > 0.05$).

Conclusions High-intensity zones occurred frequently at lower segments, inferior part of annulus fibrosus, and single disk.

Keywords Intervertebral disc · MRI · High-intensity zone · Lumbar spine · Low back pain

Introduction

High-intensity zone (HIZ) of lumbar intervertebral disc is a high-intensity signal located in the posterior annulus fibrosus on T2-weighted magnetic resonance images. It is surrounded by the low-intensity signal of the annulus fibrosus. In 1992, Aprill and Bogduk [1] have reported a strong correlation between annular high-intensity zones on lumbar MR imaging and the results of provocative discography in patients with low back pain (LBP), and believe that HIZ is a marker for painful internal disc disruption (IDD). Compared with discography, MR scan is considered more sensitive and a noninvasive procedure. In the following decades, a series of correlative researches have been carried out in symptomatic and/or asymptomatic patients [2–11]. Nevertheless, few studies are performed to describe the three-dimensional distribution of HIZ, especially the correlation between low back pain and the spatial distribution of HIZ on lumbar MR images. Therefore, there is a need to explore the distribution of HIZ in clinical practice. This study retrospectively reviewed 3,115 discs of 623 cases on lumbar MR images. The purposes of this study are to analyze the three-dimensional distribution of HIZs in different motion segments on lumbar MR images and to assess the correlation between low back pain and HIZs in different area of lumbar discs.

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Materials and methods

Subjects

The protocol was approved by the institutional ethics review board at the medical college of Qingdao University. Informed consent was not required because the images of the patients had already been obtained and were anonymous. Patients were not excluded from this study unless the records were not in their integrity, or the structure of spine was disordered, or the presence of other painful diseases such as infection, tumor, trauma, spondylolisthesis, lumbar spinal stenosis syndrome, or metabolic bone disease was evident. If there were two or more records of one patient, only the latest one was included. Finally, the clinical records and MR images of 623 patients (3,115 discs) who underwent lumbar spine MR imaging between October of 2003 and September of 2006 were selected and reviewed. Among the 623 patients, 45.9% were women ($n = 286$) and 54.1% were men ($n = 337$). The age of the patients ranged from 16 to 86 years with a mean age of 50.10 (SD 15.38).

MR imaging

Lumbar spine MR imaging of the included patients were performed with a 1.5 Tesla MR system (Signa, GE Medical System, Milwaukee, WI). All patients were examined in the supine position and the sagittal T1-weighted spin echo (repetition time 450–500 m/s, echo time 15–20 m/s, 256×192 matrix, section thickness 3–4 mm, intersection gap 0.5–1 mm), sagittal T2-weighted spin echo (repetition time 2,200–3,500 m/s, echo time 90–120 m/s, 256×192 matrix, section thickness 3–4 mm, intersection gap 0.5–1 mm) and axial T2-weighted spin echo (repetition time 2,400–3,500 m/s, echo time 90–120 m/s, 256×256 matrix, section thickness 4 mm, intersection gap 0.5 mm) MR imaging were obtained with a fixed imaging protocol. The images were collected and stored in the picture archiving and communications system (PACS; GE centricity, GE healthcare) or as printed film hard copies.

Assessment and data collection

All MR images were presented on printed films or terminal display monitors of PACS. The presence and location of annular HIZ were determined blindly by two experienced radiologists, i.e., they were unaware of any demographic and clinical data of the patients. The readings were separate and independent proceedings, which followed the original description of Aprill and Bogduk [1], but included both posterior and posterolateral annular HIZ [2]. The HIZs located in similar position of the same disc on adjacent images were counted as one.

Three-dimensional localization method was described as follows: (a) posterior annular HIZ signs on sagittal T2-weighted MR images were distinguish; (b) target HIZ in left, middle, or right part of annulus fibrosus were located according to the relative position to mid-sagittal plane on scout view; and (c) a straight line was drawn across the midpoint of ventral edge and the midpoint of dorsal edge of the lumbar disc on sagittal view. The location of the HIZ was confirmed in accordance with the relative position to the line, and characterized as a HIZ in superior, middle, or inferior annulus.

The study was conducted from September of 2005 to July of 2007. Data collection efforts ceased 8 weeks after the last required patient record was analyzed. Baseline characteristics, such as gender and age, were recorded. Orthopedic doctors made their diagnosis of LBP after studying the patient's symptoms. Accurate results of 3D localization performed by two radiologists were recorded by the researchers. All data were entered into SPSS software for analysis.

Statistical analysis

Measurement data were expressed as the mean, standard deviation (SD) and range. Enumeration data were expressed as proportions. Differences of ratios were compared using Pearson Chi-square tests for categorical variables. Adjacent categories were combined when the expected values in the cells (more than 20%) of a contingency table were below five. For all of the statistical tests, $P < 0.05$ was considered statistically significant. Statistical analyses were performed using Statistical Package for Social Sciences (SPSS 15.0 for Windows, SPSS Inc., Chicago, IL).

Results

Among the 623 patients, 200 (32.1%) exhibited an HIZ in at least one disk. All HIZs in the 238 disks were found in the posterior and posterolateral annulus on MR images. Among these 238 HIZs, 140 were in the inferior part of posterior annulus fibrosus, whereas only 59 and 39 HIZs were found in the middle part and the superior part of posterior annulus fibrosus, respectively. Pearson Chi-square testing showed that the percentages of HIZs in these three regions were significantly different ($P < 0.001$) (Table 1). There were 92 HIZs occurred in the left posterolateral annulus. The ratio of HIZs in left, middle, and right regions was 92:81:65. The distributions were symmetric in disk ($P = 0.098$, χ^2 test) (Table 1).

Most HIZs occurred at lower segments of lumbar spine. A total of 181 HIZs (76.1%) were found at L4/5 and L5/S1,

Table 1 Spatial distribution of posterior and posterolateral annular HIZ in lumbar disc ($n = 238$ HIZs)

Location	HIZ		χ^2	<i>P</i> value
	Present	Percentage (%)		
Sagittal view				
Superior	39	16.4	72.109	<0.001
Middle	59	24.8		
Inferior	140	58.8		
Total	238	100		
Coronary plane				
Left	92	38.7	4.675	0.098
Middle	81	34.0		
Right	65	27.3		
Total	238	100		

whereas only 17 HIZs (7.1%) were at L1/2 and L2/3 (Table 2).

Multi-segmental HIZs were also frequent at lower lumbar disks. L4/5 and/or L5/S1 were involved in all. Among the 33 patients with multi-segmental HIZs, 24 (72.7%) exhibited HIZs in adjacent lumbar disks. The incidence of multi-segmental HIZ was only 16.5% (Table 3).

In this study, 57.5% of HIZ patients were symptomatic, which was significantly higher than the percentage of patients who exhibited no HIZ ($P = 0.023$, χ^2 test) (Table 4). There was no evidence of a correlation between low back pain and spatial distribution of HIZ in disk ($P > 0.05$) (Table 5). Although the incidence of low back pain was higher when the HIZ disk level was lower, or HIZs were in more disks of lumbar spine of the patient, this was statistically insignificant ($P > 0.05$) (Tables 5, 6).

Discussion

High-intensity zone of lumbar disk commonly refers to a high T2 signal in the posterior and/or posterolateral

Table 2 Segmental distribution of posterior and posterolateral annular HIZ on lumbar MR images ($n = 238$ discs)

Disk level	Lumbar disk with HIZ	
	n	Percentage (%)
L1/2	7	2.9
L2/3	10	4.2
L3/4	40	16.8
L4/5	106	44.6
L5/S1	75	31.5
Total	238	100.0

Table 3 Distribution of HIZ in single or multiple disks on lumbar MR images ($n = 200$ patients)

Lumbar disk with HIZ		Patients	
n	Location	n	%
1	L1/2	5	83.5
	L2/3	4	
	L3/4	26	
	L4/5	79	
	L5/S1	53	
	Total	167	
2	L2/3 + L4/5	1	14.5
	L2/3 + L5/S1	1	
	L3/4 + L4/5	7	
	L3/4 + L5/S1	5	
	L4/5 + L5/S1	15	
	Total	29	
3	L1/2 + L2/3 + L4/5	1	1.5
	L2/3 + L3/4 + L4/5	1	
	L2/3 + L4/5 + L5/S1	1	
	Total	3	
4	L1/2 + L2/3 + L3/4 + L4/5	1	0.5
	Total	1	
Total		200	100.0

Table 4 Correlation between LBP and HIZ in 623 patients

HIZ	n	LBP*		
		Symptomatic patients	Asymptomatic patients	%
Present	200	115	85	57.5
Absent	423	202	221	47.8

* $\chi^2 = 5.161$, $P = 0.023$

annulus of lumbar spine. Most studies suggest that there is a strong correlation between annular HIZ on lumbar MR images and the results of provocative discography in patients with LBP [3–5]. For examples, Peng et al. [6] have harvested 11 specimens of lumbar intervertebral discs containing HIZs in the posterior annulus for histological examinations, and have demonstrated that the HIZs in the patients with low back pain (LBP) represent the in-growth of the vascularized granulation tissue into the tears in the posterior part of the painful disk. One previous study [12] indicates that the granulation tissue or neovascularization in annular tears are induced by inflammation. Other studies [6, 13] suggest that the inflammatory granulation tissue produces proinflammatory cytokine and mediators that can sensitize the nociceptors within the painful discs. Discogenic low back pain may occur when the intradiscal pressure increases with trunk motion. Therefore, it is believed

Table 5 Correlation between LBP and spatial/disk distribution of HIZ in single HIZ patients ($n = 167$ patients)

Location	<i>n</i>	LBP			χ^2	<i>P</i> value
		Symptomatic Patients	Asymptomatic Patients	%		
Coronary plane						
Left	64	37	27	57.8	0.294	0.863
Middle	53	28	25	52.8		
Right	50	28	22	56.0		
Sagittal view						
Superior	29	19	10	65.5	1.648	0.439
Middle	33	19	14	57.6		
Inferior	105	55	50	52.4		
Disk level						
L1/2	5	2	3	40.0	6.887*	0.076
L2/3	4	0	4	0.0		
L3/4	26	15	11	57.7		
L4/5	79	41	38	51.9		
L5/S1	53	35	18	66.0		

* Two categories (L1/2 and L2/3) have merged

Table 6 Correlation between LBP and number of HIZ disks per patient ($n = 200$ patients)

Number of HIZ disks per patient	n	LBP			χ^2	P value
		Symptomatic patients	Asymptomatic patients	%		
1	167	93	74	55.7	1.359*	0.244
2	29	18	11	62.0		
3	3	3	0	100.0		
4	1	1	0	100.0		

* Compared single HIZ disk group with multiple HIZ disks group (2–4 HIZ disks/patient)

that HIZ is a reliable marker for painful outer annular disruption.

Because of the characteristics of posterior annulus, such as the structurally weak annulus and high stress concentrations, there are more disruptions and HIZs in this region than in anterior annulus [11]. In this study, the prevalence of HIZ was up to approximate 32.1%.

Annular disruption is an important pathologic change of degenerative disk [14]. The high-intensity zone of lumbar disk, a reliable sign of annular disruption [7, 8], is also associated with disk degeneration. Aprill and Bogduk [1] have discovered that HIZs correlate significantly with the grade 4 annular disruption. Our study reveals that there are more HIZs in the lower lumbar segments than in the upper segments, and HIZ mainly occurs at the L4/5 and L5/S1 disk. This result is consistent with the reported data of Lam et al. [5], and accords with the regularity of degeneration in the lumbar spine. Therefore, HIZ observed on MR images likely indicates some stages in the disk degenerating process.

On T2-weighted images, HIZ was found in either one lumbar disk or several lumbar disks (two to five disks). Among the 200 HIZ patients in our study, only as low as 33 (16.5%) showed two or more HIZ disks on their MR

images. Most of these patients (29/33) showed two HIZ disks, whereas only a few patients (4/33) had three or four HIZ disks. Disk degeneration and disruption may lead to subsequent mechanical changes in the lumbar spine, and then accelerate the degenerative process of adjacent segments, which is correlated with HIZ. In the current study, HIZs in the adjacent disks were found on lumbar spine images in 24 of 33 patients who underwent HIZs in multiple disks. Combined HIZ frequently occurred adjacent to another HIZ disk. Two-level HIZs were found in various combinations of lumbar disks, but mainly occurred in L4/5 + L5/S1 (51.7%) and L3/4 + L4/5 (24.1%) in the current study. We conducted a review of 623 cases and detected only a few multi-level HIZs on single image. Consequently, the whole series of T2-weighted MR image slices are required in diagnosis procedure, especially when multi-level HIZs is suspicious.

Aprill et al. [1] have discovered that HIZ has a positive predictive value of 86% for a severely disrupted, symptomatic disc on CT/discography, which appears to be a breakthrough in the diagnosis of LBP. However, many studies since then either support or question the hypothesis [2, 4, 5, 7, 15], and the sensitivity and specificity of HIZ for LBP are both at variance. Therefore, HIZ may be a part of

lumbar MR image for some people, but it is certainly not the whole story. In this study, there is a great variation in the symptoms of the patients who present or lack HIZ. Therefore, the clinical relevance of HIZ with LBP is still unclear.

Some of the limitations of this study are the following. First, some cells had low counts, which may contribute to the bias in statistics. Therefore, a bigger sample population is needed in future studies. Second, CT/discography (CTD), the gold standard for discogenic pain, was not performed in this study. Computed tomographic discography is advanced in the screening of LBP patients and more reliable than exclusion diagnosis used for discogenic low back pain in our study. However, less than enough subjects have received CTD for differential diagnosis of LBP. Third, the study population was a convenient sample of patients in the hospital. It is likely that many people outside the hospital would have been different from our study population. Therefore, further studies are needed to explore the spatial distribution and correlation of distribution with LBP in other people.

Conclusions

In conclusion, we demonstrate a high prevalence of HIZ on lumbar spine MR images in our study population. High-intensity zones occur frequently at lower segments of lumbar spine, inferior part of annulus fibrosus, and single disk. The incidence of low back pain was higher when the HIZ disk level was lower or HIZs exhibited in more disks of one's lumbar spine, even though the tendencies were statistically insignificant.

Conflict of interest None.

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