Prevalence of High-Intensity Zones in the Lumbar Spine According to Age and Their Correlation with Other Degenerative Findings on Magnetic Resonance Imaging

Makoto Takeuchi[1)], Akihiro Nagamachi[2)], Keisuke Adachi[1)], Kazumasa Inoue[1)], Yasuaki Tamaki[1)], Yasuyuki Omichi[1)], Takashi Chikawa[3)] and Koichi Sairyo[2)]

1) Department of Orthopedics, Mitoyo General Hospital, Kanonji, Japan
2) Department of Orthopedics, Tokushima University, Tokushima, Japan
3) Department of Orthopedics, Tokushima Municipal Hospital, Tokushima, Japan

Abstract:

Introduction: A high-intensity zone (HIZ) in an intervertebral disc of the lumbar spine is a high-intensity signal located in the posterior annulus fibrosus on T2-weighted magnetic resonance imaging (MRI). There is limited information on the prevalence of HIZ in the lumbar spine according to age. The aim of this cross-sectional study was to investigate the prevalence of HIZ in the lumbar spine by age and the correlation between HIZ and other degenerative findings, such as disc degeneration, disc bulging and herniation, and changes in adjacent vertebral endplates on lumbar MRI.

Methods: We retrospectively reviewed MRI studies of 305 patients (1525 discs) with low back pain, leg pain, or numbness. The prevalence of HIZ was calculated in 5 age groups (<20, 20-39, 40-59, 60-79, 80-91 years).

Results: The number of patients in the 5 age groups was 19, 38, 69, 145, and 36, respectively. The prevalence of HIZ in the 5 age groups was 11.8%, 47.3%, 52.2%, 42.8%, and 50.0%, respectively. Disc degeneration was observed in 58.1% and 39.2% of discs with and without HIZ, respectively; disc bulging and herniation was observed in 63.9% and 41.1% and intensity changes at adjacent end plates in 11.6% and 10.0%, respectively.

Conclusions: Prevalence of HIZ from the third decade of life onward was around 50%, with no significant change in prevalence beyond the age of 20 years. HIZ was correlated with disc degeneration, disc bulging, and disc herniation in patients with LBP, leg pain, or numbness.

Keywords:

High-intensity zone, lumbar spine, MRI, Low back pain, Intervertebral disc

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Introduction

The term "high-intensity zone" (HIZ) was coined in 1992 by Aprill and Bogduk to describe a high signal within the annulus of a disc, separated from the nucleus pulposus, seen on magnetic resonance imaging (MRI) of the lumbar spine[1)]. HIZ has a positive predictive value of 86% for a severely disrupted and painful disc. Some investigators[2,3)] believe that the presence of HIZ is closely associated with a concordant pain response on awake discography, whereas others[4-6)] do not. The correlation between HIZ and low back pain (LBP) has been investigated, however, few studies have described the prevalence of HIZ in the lumbar spine according to age or investigated the correlation between HIZ and other degenerative findings on lumbar MRI.

The purpose of this study was to investigate the correlation between HIZ and LBP, the prevalence of HIZ in the lumbar spine by age, and the correlation between HIZ and other degenerative findings on lumbar MRI, such as disc degeneration, disc bulging and herniation, and adjacent vertebral endplate changes.

Materials and Methods

We undertook a retrospective analysis of 305 consecutive patients (139 male, 166 female) who had undergone MRI of

Corresponding author: Makoto Takeuchi, tolivetube@gmail.com
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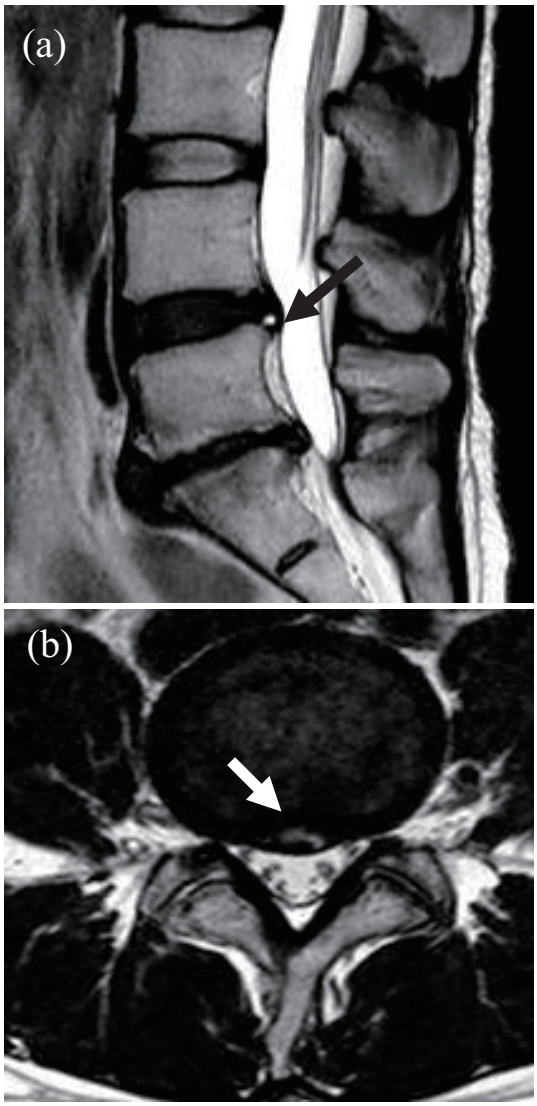

Figure 1. (a) Sagittal T2-weighted magnetic resonance image showing a high-intensity zone (arrow) within the posterior annulus at L3-4. (b) Axial T2-weighted magnetic resonance image showing a high-intensity zone (arrow) within the posterior annulus at L3-4.

the lumbar spine (including 1525 discs) between April 2013 and August 2015. Patients who had one or more symptoms of LBP, leg pain, and numbness were included. The patients without LBP also undertook MRI when they possibly suffered from lumbar diseases. The protocol was approved by the institutional ethics review board at Mitoyo General Hospital. Informed consent was not required because the images of the patients had already been obtained and were anonymous. Patients who were diagnosed with infectious spondylitis, tumors, and who had previous surgical procedures were all excluded from this study. If there were two or more records of one patient, only the latest one was included. Mean age was 59.3 (2-91) years. Patients were divided into 5 age groups: <20 years (n = 19), 20-39 years (n = 38), 40-59 years (n = 69), 60-79 years (n = 145), and ≥80 years (n = 36). Prevalence of HIZ was calculated according to age group. A 1.5 T MRI scanner (Ingenia MR-RT, Philips, Amsterdam, The Netherlands) was used to acquire the images. T1-weighted (400 < repetition time < 450 m/sec; echo time = 8 m/sec) and T2-weighted (3100 < repetition time < 3200; echo time = 100 m/sec) spin echo images were taken in the sagittal and axial planes. All MR images had a slice thickness of 4 mm. HIZ was defined as a bright white signal located in the substance of the posterior annulus fibrosus that was clearly dissociated from the signal of the nucleus pulposus by being surrounded by the low intensity (black) signal of the annulus fibrosus and was appreciably brighter than that of the nucleus pulposus on T2-weighted sagittal MR images (Fig. 1).

We analyzed the prevalence of HIZ in the patients with LBP or without LBP and that of HIZ in 5 age groups as above. Correlations between HIZ and other degenerative findings on lumbar MRI, such as disc degeneration, disc bulging and herniation, and changes in adjacent vertebral endplates were evaluated.

The degree of disc degeneration was assessed on T2-weighted images using the Pfirrmann grading system as follows: 1, normal structure, no horizontal bands, clear distinction between annulus and nucleus; 2, inhomogeneous structure with horizontal bands, clear distinction between nucleus and annulus; 3, inhomogeneous structure with unclear distinction between nucleus and annulus, features of annulus still recognizable; 4, inhomogeneous structure with hypointensity, shape of annulus not intact and no distinction between nucleus and annulus, disc height usually decreased; and 5, same as grade 4 but disc space is collapsed[7]. Grades 1-3 were classified as normal disc and grade 4-5 as degenerated disc.

Disc displacement was categorized into herniation and bulging based on the classification of disc displacement by Fardon et al. Herniation was defined as displacement of disc material involving less than 50% of the disc circumference. Bulging was defined as displacement of disc material involving greater than 50% of the disc circumference[8].

Vertebral endplate and bone marrow changes were graded as absent, type I (hypointense in T1-weighted sequences and hyperintense in T2-weighted sequences), type II (hyperintense in both sequences), and type III (hypointense in both sequences) as demonstrated by Modic et al[9].

Differences of ratios were compared using Chi-square tests. For all of the statistical tests, $P < 0.05$ was considered statistically significant. Statistical analyses were performed using Statistical Package for Social Sciences (SPSS version 23.0 for Windows, SPSS Inc., Chicago, IL).

Results

Of 305 patients, 136 patients (44.5%) had HIZ in at least one disc. HIZ was found in 67 of 151 patients with LBP (44.3%) and 69 patients of 154 patients without LBP (44.8%). There was no statistically significant difference between the two groups (Table 1). HIZ was observed more

Table 1. Comparison between the Presence and Absence of HIZ and LBP in 305 Patients.

LBP	*n*	HIZ		
		Present	Absent	%
Present	151	67	84	44.3
Absent	154	69	85	44.8

All non-significant, chi-squared test.
LBP, low back pain; HIZ, high-intensity zone

Table 2. Percentage of 1525 Lumbar Discs with HIZ according to Disc Level.

Lumbar disc with HIZ		
	n	%
L1-2	0	0.0
L2-3	18	5.9
L3-4	27	8.9
L4-5	60	19.7
L5-S1	67	22.0
Total	172	100.0

HIZ, high-intensity zone

Table 3. Patients with HIZ (*n*=305) according to Age Group.

Age, years	*n*	HIZ		
		Present	Absent	%
0-19	17	2	15	11.8*
20-39	38	18	20	47.3
40-59	69	36	33	52.2
60-79	145	62	83	42.8
>80	36	17	17	50.0

* P=0.011 vs. 20-39, P=0.0027 vs. 40-59, P=0.013 vs. 60-79, P=0.0078 vs. 80-91, chi-squared test.
HIZ, high-intensity zone

Table 4. Percentage of 135 Patients with HIZ and LBP according to Age Group.

Age, years	*n*	LBP		
		Present	Absent	%
0-19	2	2	0	100.0
20-39	18	12	6	66.7
40-59	36	17	19	47.2
60-79	63	28	35	44.4
>80	17	9	8	52.9

All non-significant, chi-squared test.
LBP, low back pain; HIZ, high-intensity zone

Table 5. (a) Correlation between Disc Degeneration and HIZ. P=0.033, Chi-squared Test. (b) Correlation between Disc Bulging or Herniation and HIZ. P=0.0004, Chi-squared Test. (c) Correlation between Modic Change and Presence or Absence of HIZ. All Non-significant, Chi-squared Test. HIZ, High-intensity Zone

HIZ	*n*	Disc degeneration		
		Grades 4-5	Grades 1-3	%
Present	172	100	72	58.1
Absent	1353	531	822	39.2

HIZ	*n*	Disc bulging or herniation		
		Present	Absent	%
Present	172	110	62	63.9
Absent	1353	556	797	41.1

HIZ	*n*	Modic change		
		Present	Absent	%
Present	172	20	152	11.6
Absent	1353	136	1217	10.0

often at L4-5 (60/305 discs, 19.7%) and L5-S1 (67/305 discs, 22.0%; Table 2). The prevalence of HIZ in patients aged <20, 20-39, 40-59, 60-79, and 80-91 years was 11.8% (2/17), 47.3% (18/38), 52.2% (36/69), 42.8% (62/145), and 50.0% (17/34), respectively. Prevalence of HIZ in the first and second decades of life was significantly lower than in the other age groups (P = 0.011 vs. 20-39, P = 0.0027 vs. 40-59, P = 0.013 vs. 60-79, P = 0.0078 vs. 80-91), but there was no significant difference in prevalence between the other age groups (Table 3). The percentage of patients with HIZ and LBP in the respective age groups was 100% (2/2), 66.7% (12/18), 47.2% (17/36), 44.4% (28/63), and 52.9% (9/17). There was no significant difference in the frequency of HIZ and LBP in any of the age groups (Table 4).

Disc degeneration was observed in 58.1% (100/172) and 39.2% (531/1353) of discs with and without HIZ, respectively. The prevalence of degeneration in discs with HIZ was significantly higher than that in discs without HIZ [P = 0.033; Table 5 (a)]. Disc bulging and herniation were observed in 63.9% (110/172) and 41.0% (556/1353) of the discs with and without HIZ, respectively. Prevalence of bulging or herniation in discs with HIZ was significantly higher than that in those without HIZ [P = 0.0004; Table 5 (b)]. Changes in adjacent endplates were observed in 11.6% (20/172) and 10.0% (136/1353) of discs with and without HIZ, respectively. No significant difference was observed between the two groups [P = 0.52; Table 5 (c)].

Discussion

HIZ on MRI images was first described by Aprill and Bogduk in 1992[1]. HIZ is believed to represent the detached nucleus pulposus trapped between the lamellae of the torn annulus fibrosus following secondary inflammation, causing a characteristic signal on MRI. The presence of granulation

tissue or neovascularization induced by inflammation was demonstrated by Ross et al.[10]. Most of the nerve supply of the intervertebral disc is limited to the periphery of the annulus fibrosus[11]. Therefore, an annular tear extending to the inner third of the annulus fibrosus is asymptomatic, whereas a tear extending to the peripheral third produces pain[11]. However, some reports have shown that there was no relationship between LBP and HIZ; therefore, the diagnostic value of HIZ is still controversial. Schellhas et al.[3] examined symptomatic subjects with at least one HIZ-positive disc on MRI and found that 87% of the HIZ-positive discs were concordantly painful with discography and that discography did not elicit concordant pain in 65 of 67 HIZ-negative discs. They concluded that the presence of HIZ was a sign of symptomatic disruption of an internal disc. In contrast, Ricketson et al.[12] reported that although HIZs were not found in normal discs, there was no significant correlation between the presence of HIZ and concordant pain with discography. Carragee et al.[13] also noted that HIZ was found on MRI in 24% of asymptomatic subjects, and in patients who were positive for HIZ, the rate of positive results with discography did not differ between the symptomatic and asymptomatic groups. They concluded that HIZ could not be considered a specific finding with internal disc disruption. In the present study, there was no significant relationship between LBP and HIZ in the age groups of over 20 years. Based on these results, the diagnostic value of HIZ in adult patients with LBP is uncertain.

Lam et al.[14] demonstrated a significant correlation between abnormal disc morphology and the presence of HIZ. Subash et al.[15] reported that the presence of HIZ was directly correlated with increased incidence of lumbar disc degeneration and that the prevalence of degeneration was significantly higher in patients with HIZ in the lower three lumbar levels. Our result was consistent with that of previous studies. The prevalence of HIZ in the lower two lumbar level (L4-5, L5-S1) is higher than the upper ones.

Kun-Woo et al.[16] found that the prevalence of HIZ was significantly higher in patients in the fourth decade of life. They also demonstrated that degeneration of disc material and radial tear of the posterior annulus was caused by spinal instability and serial degenerative disc changes, such as decreased content of water and glycosaminoglycan and an imbalance between tissue matrix metalloproteinase MMP and tissue inhibitors of matrix metalloproteinases (TIMPs) levels. In our research, the prevalence of HIZ in the first and second decades of life was significantly lower than that in the other age groups and that of HIZ in those aged over 20 years was around 50%. Young patients with normal discs had a lower incidence of HIZ, and elderly patients with degenerated discs had a higher incidence of HIZ, indicating a close relationship between disc degeneration and HIZ. HIZ was found in only 2 patients aged younger than 20 years, but both patients had LBP. In contrast, many patients over the age of 60 years who had multiple lumbar discs with HIZ had no LBP in this study. Therefore, we speculate that the pathogenesis of HIZ in younger patients may differ from that in elderly patients. The diagnostic value of HIZ in patients under 20 years of age may be higher than that in older patients with marked disc degeneration. Unfortunately, only 2 patients had symptomatic HIZ in this study. Further research regarding the correlation between HIZ and LBP in younger patients under 20 years of age is needed.

Some of the limitations of this study are the following. First, we included a small number of patients aged younger than 20 years, which may contribute to the bias in statistics. Therefore, a bigger sample population is needed in future studies. Second, it was not clear that LBP of the patient in this research was caused by HIZ. LBP is the result of variable disorder in the lumbar region such as osteoarthritis of the facet joint, spinal deformity, or muscle weakness of the low back, etc. Confirming whether HIZ in the patient is the cause of LBP by discography is necessary; however, that is difficult because of retrospective study design.

Conclusion

The prevalence of HIZ in the first and second decades of life was significantly lower than that in the other age groups. However, there was no significant change in the prevalence of HIZ beyond the age of 20 years. HIZ showed a close correlation with disc degeneration, bulging, and herniation in patients with LBP, leg pain, or numbness. LBP and HIZ were not significantly correlated in patients older than 20 years. In view of these results, the diagnostic value of HIZ in adult patients with LBP remains uncertain.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Makoto Takeuchi wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

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