Acta Orthop. Belg., 2019, **85**, 47-53

ORIGINAL STUDY

Prevalence of lumbar high-intensity zone: assessment using a screening tool independent of spinal symptoms

Mauricio Campos, Raimundo Vial, Javier Castro, Julio Urrutia

From the Department of Orthopaedic Surgery, School of Medicine, Pontificia Universidad Catolica de Chile

High-intensity zone is an area of high-intensity signal within the posterior annulus fibrosus observed in magnetic resonance imaging; initially described in painful discs, recent studies have described similar prevalence in symptomatic and asymptomatic subjects. Since its' prevalence in the general population has not been established, we used a screening tool independent of spinal symptoms to determine high-intensity zone prevalence. We studied 217 patients evaluated with abdominal-pelvic magnetic resonance imaging; we looked for high-intensity zone, disc degeneration, spondylolysis, spondylolisthesis, Modic changes and scoliosis. We determined if these variables, age and sex affected the presence of high-intensity zone; through a logistic regression analysis we evaluated their independent effect. Patients' mean age was 56.3±17.4 years; 66.8% were females. Prevalence of high-intensity zone (11.06%) was larger in males (18.06%) than females (7.59%), p = 0.02. Patients with and without high-intensity zone did not differ in age or presence of scoliosis. High-intensity zone was more frequent in degenerated discs, but not in levels with spondylolisis, spondylolisthesis or Modic changes. Male sex (OR = 2.3, 1.04-5.38) and disc degeneration (OR = 6.76, 1.77-25.81) independently influenced the presence of high-intensity zone.

The prevalence of high-intensity zone in this sample of the general population, including 217 subjects, was 11.06%. Similarly, a recent meta-analysis mentioned a 9.5% prevalence in asymptomatic subjects; on the other hand it stressed a 10.4% prevalence in symptomatic subjects. All these data do not plead for a strict correlation between high-intensity zone and low back pain complaints.

Keywords : High-intensity zone ; disc degeneration ; prevalence study ; lumbar spine.

INTRODUCTION

Magnetic resonance imaging (MRI) is currently considered the gold standard to evaluate patients with spinal degeneration. MRI not only shows disc morphology but also displays disc hydration as well as several disc-related and bone-related findings associated with spinal degeneration (e.g., Modic changes). It is well-known that many of these degenerative changes can be observed in asymptomatic subjects *(2,3,5,9)*, and their prevalence rises with increasing age *(2,9)*. Among the different findings that can be observed through MRI in the lumbar spine, the high-intensity zone (HIZ) has been evaluated in several studies *(3,4,11,13, 19,20,27)*. This sign was originally described by

■ Mauricio Campos,
■ Raimundo Vial,
■ Javier Castro.
■ Julio Urrutia,
Department of Orthopaedic Surgery, School of Medicine, Pontificia Universidad Catolica de Chile.
Correspondence : Julio Urrutia, MD, Department of Orthopaedic Surgery, Pontificia Universidad Catolica de Chile, Marcoleta 352, Santiago, Chile. Telephone: 562-23543467
E-mail : jurrutia@med.puc.cl

All named authors hereby declare that they have no conflicts of interest to disclose.

Aprill et al. as a "high-intensity signal (bright white) located in the substance of the posterior annulus fibrosus, clearly dissociated from the signal of the nucleus pulposus in that it is surrounded superiorly, inferiorly, posteriorly and anteriorly by the low-intensity (black) signal of the annulus fibrosus and is appreciably brighter than that of the nucleus pulposus" *(1)*.

Aprill et al. considered the HIZ to be equivalent to internal disc disruption, a condition that initially could only be demonstrated through a discography *(23)*. Moreover, because discography at that time was considered a very specific test (therefore, not painful in asymptomatic subjects) *(24)*, HIZ was thought to represent a diagnostic sign of a painful lumbar disc *(1,12,15)*. However, later studies showed that provocative discography can induce pain even in people without previous back pain *(4)*, and psychosocial factors seem to be the most predictive factor to determine which patients undergoing a provocative discography will experience pain *(4)*. Additionally, more recently it has been noted that HIZ can frequently be found in asymptomatic patients *(3,4,7,13)*. Although some studies showing that the prevalence of HIZ is lower in asymptomatic patients, a recent meta-analysis failed to demonstrate such a divergent prevalence of HIZ in symptomatic and asymptomatic populations *(3)*; thus, the controversy regarding its role as pain generator continues *(8)*. Furthermore the prevalence of HIZ in the general population has not been clearly established.

Taking into consideration that many patients with HIZ can be asymptomatic, the research instruments to study its prevalence should include a screening tool independent of those used for spinal symptoms to minimize selection bias. Such a strategy would better reflect the true prevalence of HIZ in the general population, in contrast with previous studies, which have been conducted either in patients evaluated with MRI of the lumbar spine (thus focusing on symptomatic subjects) or in volunteers, which introduces potential selection bias and overestimates asymptomatic HIZ prevalence. Abdominal and pelvic MRI scans, especially the sagittal views, allow for an accurate visualization of the lumbar spine (Figure 1) *(22)*, so creating an interesting opportunity to study the spine regardless of spinal complaints, as they are frequently indicated for the study of non-spinal abdominal or retroperitoneal pathology.

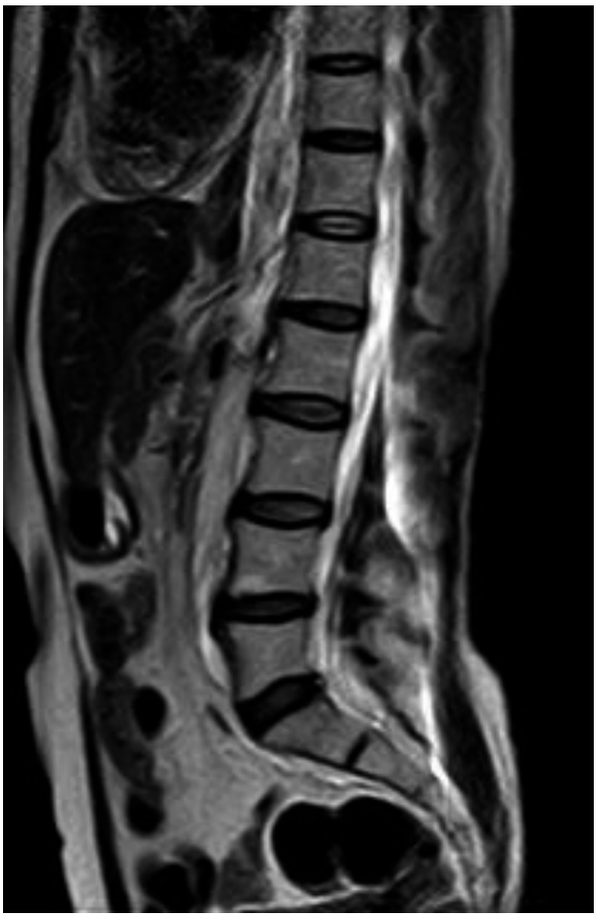

Fig.1. — Sagittal view of MRI (T2 sequence) showing the entire lumbar spine

The aim of this study was to determine the prevalence of HIZ in adults, using abdominal and pelvic MRI as a screening tool. As a secondary objective, we sought to determine the relationship between HIZ and age, sex, disc degeneration and the presence of olisthesis in the same level or of scoliosis in the lumbar spine.

MATERIALS AND METHODS

Institutional Review Board approval was obtained to conduct this study. We studied 217 adult patients who consecutively underwent abdominal and pelvic MRI at a tertiary care university hospital.

Table I. — Indications for the MRI scan

	Number of cases	Percentage
Malignancy	85	39.2
Abdominal or pelvic pain	75	34.6
Gynecological disease	14	6.5
Biliary or hepatic disease	14	6.5
Post operative control	6	2.8
Infectious disease	6	2.8
Others	15	6.9
Not available	2	0.9
Total	217	100

The images were requested for a variety of reasons unrelated to the spine, including fever, suspicion of abdominal or pelvic malignancy or infection, and examination of malignancies under treatment, among other causes. We examined the indications in every patient to verify that the studies were not requested for lumbar symptoms (Table I). The exclusion criteria were the presence of tumors or instrumentation in the lumbar spine or an insufficient visualization of the whole lumbar spine. Fourteen patients were excluded using these criteria (all were excluded because adequate visualization of the entire lumbar spine was not possible). If a single patient underwent two or more studies, only the most recent one was included.

MRI scans were obtained using a 1.5-T unit (Siemens Magnetom Avanto; Siemens Medical Solutions, Erlangen, Germany or Philips Achieva; Philips Healthcare Best, The Netherlands). MRI sequences included: T2 images in the axial, sagittal and coronal planes, T1 images in the axial and coronal planes, T2-weighted images with fat saturation in the sagittal plane, and diffusion-weighted images in the axial plane; 4 mm slice thickness was used in all sequences. The MRIs and the official reports were reviewed using the Impax Web3000 program (Agfa-Gevaert, Mortsel, Belgium), which is available at our institution.

In order to increase sensibility detecting HIZ, all of the MRIs scans were evaluated independently by two of the authors, in a blinded fashion regarding the clinical and personal data. The entire lumbar and sacral spine was evaluated in each patient using sagittal and axial views. We scanned for HIZ according to the definition mentioned above: "high-intensity signal (bright white) located in the substance of the posterior annulus fibrosus, clearly dissociated from the signal of the nucleus pulposus in that it is surrounded superiorly, inferiorly, posteriorly and anteriorly by the low-intensity (black) signal of the annulus fibrosus and is appreciably brighter than that of the nucleus pulposus" *(1)*, as shown in Figures 2 and 3. In addition to search for HIZ in the dorsal annulus fibrosus, we also looked for HIZ in ventral locations; we used the same diagnostic criteria, but for high-intensity signal located in the substance of the anterior annulus fibrosus. We also classified each lumbar disc according to the Pfirrmann grading for disc degeneration *(16,21)*. Furthermore, we evaluated the presence of endplate changes (Modic changes), either type I (hypointense on T1-weighted sequences and hyperintense on T2-weighted sequences), type II (hyperintense on both sequences) or type III (hypointense on T1- weighted sequences and hypointense on T2-weighted sequences) *(25)*. Finally, we evaluated the presence of spondylolysis and spondylolisthesis at every level, as well as the existence of scoliosis in the lumbar spine.

The senior author reviewed all of the cases in which a HIZ was detected by either of the two

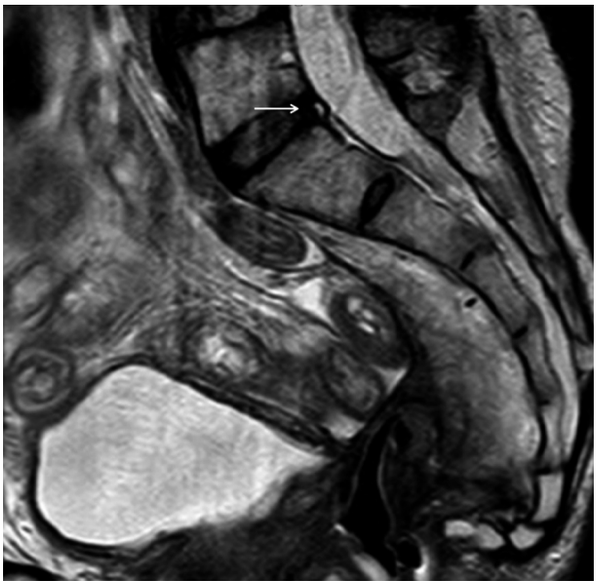

Fig. 2. — Sagittal view of MRI (T2 sequence) showing a HIZ at the L5-S1 disc (arrow)

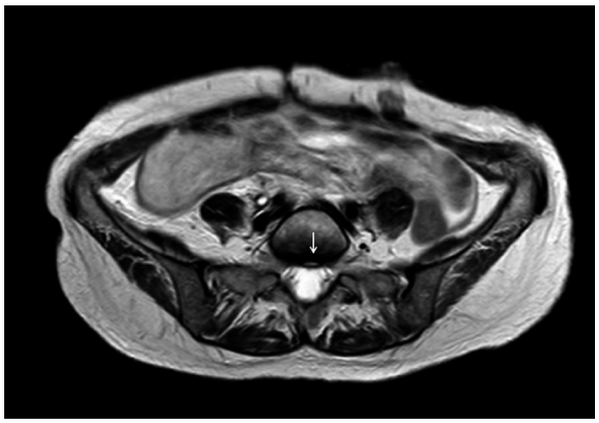

Fig. 3. — Axial view of MRI (T2 sequence) showing at the L5-S1 disc (arrow)

evaluators; they had discrepancies detecting a HIZ in three cases. The discrepancies between the two assessors were resolved by consensus of all the authors.

To determine the sample size, we used data from Carragee et al. *(4)*; assuming 24% prevalence of HIZ, using an error margin of 5% and a confidence level of 90%, the minimal sample size was 195 cases.

Statistical analyses were performed using the Statistical Program for the Social Sciences (SPSS) version 18 (SPSS, Chicago, IL). Prevalence was expressed as a proportion of patients, with a 95% confidence interval (CI). Continuous data were described as means and standard deviations, and categorical variables were expressed as percentages. We performed the Student's t-test to analyze continuous variables and Fisher's exact test for categorical variables. Lumbar scoliosis was evaluated per patient, but the presence of olisthesis, spondylolysis, Modic changes and disc degeneration were evaluated per level as the same patient could have lumbar levels with and without them. All variables with $p < 0.1$ were identified and included in a logistic regression analysis performed to determine their independent influence on the prevalence of HIZ; the results were expressed as an odds ratio (OR) with 95% CI. A p value < 0.05 was considered statistically significant.

RESULTS

We evaluated 217 patients for a total of 1,085 lumbar discs. The mean age of our patients was 56.3 ± 17.4 years; 72 patients (33.2%) were males and 145 (66.8%) were females.

The prevalence of HIZ was 11.06% (24 patients); 95% CI: 6.85 – 15.27. The disc levels that most frequently showed HIZ were L5-S1 (45.58% of discs presenting HIZ), followed by L4-L5 (33.3%); none of the patients we studied had HIZ at more than one level. The prevalence of HIZ decreased in more cephalic levels, as shown in Table II.

Table II. — Distribution of HIZ by level

Level	Number of HIZ	Percentage
L1-L2	1	4.2
L2-L3	2	8.3
L3-L4	2	8.3
L4-L5	8	33.3
L5-S1	11	45.8
Total	24	100

Considering the 1,085 discs evaluated, only 24 (2.2%) exhibited HIZ; 83.3% of patients presented a dorsally located HIZ, while only 16.7% presented it in the ventral aspect of the disc, $p < 0.01$.

Men exhibited a 18.06% prevalence of HIZ (13/72 patients), whereas women exhibited a prevalence of 7.59% (11/145 patients), $p = 0.02$. Patients with HIZ were not older (mean age = 59.5 years) than patients without HIZ (mean age = 55.9 years), $p = 0.34$. HIZ was not more prevalent either in levels with spondylolysis, spondylolisthesis, Modic changes or in patients presenting lumbar scoliosis (Table III). However, HIZ was significantly more prevalent in discs with disc degeneration (Pfirrmann grades 3, 4 or 5) than in discs without degeneration (Pfirrmann 1 or 2), $p= 0.03$, as is also shown in Table III.

Logistic regression analysis revealed that only male sex (OR = 2.3, 95% CI 1.04-5.38; $p = 0.041$) and disc degeneration (OR = 6.76, 95% CI 1.77-25.81, $p < 0.01$) were independent predictors of the presence of HIZ. Neither age (OR = 0.98; p =

Table III. — Lumbar scoliosis, olisthesis, spondylolysis, Modic changes and disc degeneration in patients with and without HIZ. Lumbar scoliosis was evaluated per patient; olisthesis, spondylolysis, Modic changes and disc degeneration were evaluated per level.

Analysis	Variable	Number of cases	Frequency in patients without HIZ (%)	Frequency in patients with HIZ	p value
Per patient analysis	Lumbar scoliosis	26	26/193 (13.47%)	0/24 (0%)	0.09
			Frequency in levels without HIZ (%)	Frequency in levels with HIZ (%)	
Per level analysis	Spondylolisthesis	78	76/1061 (7.16%)	2/24 (8.33%)	0.69
	Spondylolysis	9	8/1061 (0.75%)	1/24 (4.16%)	0.18
	Modic changes	79	75/1061 (7.06%)	4/24 (16.66%)	0.09
	Disc degeneration	623	602/1061 (56.73%)	21/24 (87.50%)	0.03

0.2) nor the presence of Modic changes at the level of the HIZ (OR = 1.86; p = 0.28) influenced the presence of HIZ.

DISCUSSION

In the original description of HIZ, this lesion was considered a diagnostic sign of a painful lumbar disc *(1)*; however, newer studies have demonstrated that HIZ is often found in asymptomatic subjects *(3,4,13)*. Considering that this sign is routinely evaluated in patients who undergo lumbar MRI, it is important to determine the prevalence of HIZ in the general population to understand its significance in the assessment of patients with low back pain *(6)*, and radicular pain *(18)*.

The original study by Aprill and Bogduk reviewed the lumbar MRI of 500 symptomatic patients *(1)*; the authors reported a 28.6% prevalence of HIZ, and L4-L5 and L5-S1 were the most frequently affected discs *(1)*. These results are similar to data from later studies in symptomatic patients *(27)*. In our study, the prevalence of HIZ was only 11.02% in a large sample of patients evaluated independently of the presence of lumbar symptoms; this is important, given that some data have shown that the prevalence of HIZ in asymptomatic subjects is lower than in patients evaluated for low back pain *(4,7,19)*. However, this finding could not be demonstrated in a recent meta-analysis comparing MRI findings of lumbar spine degeneration in adults 50 years of age and younger with and without low back pain *(3)*. While other studies have intended to determine the prevalence of HIZ, what is new from our study is that we tried to determine the prevalence of HIZ in a population independent of the presence of spinal symptoms; therefore, our data should be considered closer to the actual prevalence of this sign in the general population (which has not yet been established).

A recent study in young Finnish adults showed a lower prevalence of HIZ (3.2%) than our study; however, only patients who were 20-22 years old were studied *(20)*; such a different age range compared to our cohort may also explain the larger prevalence of HIZ that we observed in males, conversely to the data from Takatalo et al. *(20)* However, we believe our sample of patients, with a wide age range, represents a much better sample of the patients usually undergoing evaluation of their lumbar spine. Moreover, we also looked for the presence of HIZ in the anterior aspect of the disc, a finding that has been overlooked in most studies; while anterior HIZ has been described *(26)*, very scarce studies have evaluated this finding and, to the best of our knowledge, its clinical significance has not been elucidated. Another study reporting MRI lumbar degenerative findings in more than a thousand volunteers demonstrated a linear incremental prevalence of HIZ depending on age, from 8% in volunteers younger than 30 years and up to 33% in subjects older than 50 *(5)*. The difference in these results compared with our study could be related to the sampling method as

it is recognized that sampling by voluntary open call may introduce selection bias of candidates, thus overestimating the occurrence of the event of interest. Nevertheless, it may also correspond to a type II statistical error, given the overall low prevalence of the phenomena under scrutiny.

Our results show that HIZ was more frequently found at L4-L5 and L5-S1, which is in agreement with previous reports *(1,12,27)*. This is expected because these two levels are the most frequently affected by disc degeneration, but to the best of our knowledge, this is the first study demonstrating that disc degeneration is independently associated with the presence of HIZ. Notably, other variables associated with disc degeneration, such as spondylolisthesis, Modic changes, lumbar scoliosis and increasing age were not associated with the presence of HIZ. While it has been previously described that HIZ is not related to Modic changes in patients with low back pain *(14)*, other studies have linked the presence of HIZ lesions only with isthmic spondylolisthesis and not with degenerative spondylolisthesis *(10)*.

This is the first study to use abdominal and pelvic MRI as the screening tool to determine the prevalence of HIZ in the lumbar spine. The advantage of this instrument is that these images are requested in patients who present with a variety of medical conditions that are not related to the spine, but it simultaneously allows for an adequate visualization of the lumbar spine in most cases *(22)*. Nonetheless, patients being evaluated with abdominal and pelvic MRI cannot be considered a perfect sample of the normal population, which is a limitation of our study. However, even when some of these patients could have presented back pain as part of their symptoms, we verified that none of the conditions to request the studies was associated with disc degeneration. Consequently, our results should be representative of lumbar degenerative findings at this age. However, future studies using digital measurements of the signal intensity to diagnose HIZ, instead of the standard visual assessment that we used, may better determine the actual prevalence of HIZ; such a digital measurement may overcome limitations described in the assessment of HIZ *(17)*.

Using abdominal and pelvic MRI as a screening tool, we observed a prevalence of HIZ (11.06%) comparable to what was found in the largest meta-analysis published on this topic; in such study, Brinjikji et al. described a 9.5% prevalence of HIZ in asymptomatic subjects and 10.4% in symptomatic patients *(3)*. All these data do not plead for a strict correlation between HIZ and low back pain complaints.

REFERENCES

1. **Aprill C, Bogduk N.** High-intensity zone: a diagnostic sign of painful lumbar disc on magnetic resonance imaging. *Br J Radiol* 1992 ; 65 : 361-9.
2. **Boden SD, Davis DO, Dina TS, Patronas N , Wiesel S W.** Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J Bone Joint Surg Am* 1990 ; 72 : 403-8.
3. **Brinjikji W, Diehn FE, Jarvik JG,** *et al.* MRI Findings of Disc Degeneration are More Prevalent in Adults with Low Back Pain than in Asymptomatic Controls: A Systematic Review and Meta-Analysis. AJNR *Am J Neuroradiol* 2015 ; 36 : 2394-9.
4. **Carragee EJ, Paragioudakis SJ, Khurana S.** 2000 Volvo Award winner in clinical studies: Lumbar high-intensity zone and discography in subjects without low back problems. *Spine* (Phila Pa 1976) 2000 ; 25 : 2987-92.
5. **Cheung KM, Karppinen J, Chan D, Ho DW, Song YQ, Sham P,** *et al.* Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. *Spine* (Phila Pa 1976) 2009 ; 34 : 934-40.
6. **Djurasovic M, Carreon LY, Crawford CH, 3rd, Zook JD, Bratcher KR, Glassman SD.** The influence of preoperative MRI findings on lumbar fusion clinical outcomes. *Eur Spine J* 2012 ; 21 : 1616-23.
7. **Hancock M, Maher C, Macaskill P, Latimer J, Kos W, Pik J.** MRI findings are more common in selected patients with acute low back pain than controls? *Eur Spine J* 2012; 21 : 240-6.
8. **Hancock MJ, Maher CG, Latimer J,** *et al.* Systematic review of tests to identify the disc, SIJ or facet joint as the source of low back pain. *Eur Spine J* 2007 ; 16 : 1539-50.
9. **Jensen M C, Brant-Zawadzki M N, Obuchowski N,** *et al.* Magnetic resonance imaging of the lumbar spine in people without back pain. *N Engl J Med* 1994 ; 331 : 69-73.
10. **Jeong HY, You JW, Sohn HM, Park SH.** Radiologic evaluation of degeneration in isthmic and degenerative spondylolisthesis. *Asian Spine J* 2013 ; 7 : 25-33.
11. **Khan I, Hargunani R, Saifuddin A.** The lumbar high-intensity zone: 20 years on. *Clin Radiol* 2014 ; 69 : 551-8.
12. **Lam KS, Carlin D, Mulholland RC.** Lumbar disc high-intensity zone: the value and significance of provocative

discography in the determination of the discogenic pain source. *Eur Spine J* 2000 ; 9 : 36-41.

13. **Liu C, Cai HX, Zhang JF, Ma JJ, Lu YJ, Fan SW.** Quantitative estimation of the high-intensity zone in the lumbar spine: comparison between the symptomatic and asymptomatic population. *Spine J* 2014 ; 14 : 391-6.
14. **Marshman LA, Metcalfe AV, Krishna M, Friesem T.** Are high-intensity zones and Modic changes mutually exclusive in symptomatic lumbar degenerative discs? *J Neurosurg Spine* 2010 ; 12 : 351-6.
15. **Peng B, Hou S, Wu W, Zhang C, Yang Y.** The pathogenesis and clinical significance of a high-intensity zone (HIZ) of lumbar intervertebral disc on MR imaging in the patient with discogenic low back pain. *Eur Spine J* 2006 ; 15 : 583-7.
16. **Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N.** Magnetic resonance classification of lumbar intervertebral disc degeneration. *Spine* (Phila Pa 1976) 200 ; 26 : 1873-8.
17. **Riesenburger RI, Safain MG, Ogbuji R, Hayes J, Hwang SW.** A novel classification system of lumbar disc degeneration. *J Clin Neurosci* 2015 ; 22 : 346-51.
18. **Saifuddin A, Mitchell R, Taylor BA.** Extradural inflammation associated with annular tears: demonstration with gadolinium-enhanced lumbar spine MRI. *Eur Spine J* 1999 ; 8 : 34-9.
19. **Schellhas KP, Pollei SR, Gundry CR, Heithoff KB.** Lumbar disc high-intensity zone. Correlation of magnetic resonance imaging and discography. *Spine* (Phila Pa 1976) 1996 ; 21 : 79-86.
20. **Takatalo J, Karppinen J, Niinimaki J, Taimela S, Nayha S, Jarvelin MR,** *et al.* Prevalence of degenerative imaging findings in lumbar magnetic resonance imaging among young adults. *Spine* (Phila Pa 1976) 2009 ; 34 : 1716-21.
21. **Urrutia J, Besa P, Campos M, Cikutovic P, Cabezon M, Molina M,** *et al.* The Pfirrmann classification of lumbar intervertebral disc degeneration : an independent inter- and intra-observer agreement assessment. *Eur Spine J* 2016 ; 25 ; 2728-33.
22. **Urrutia J, Zamora T, Prada C.** The prevalence of degenerative or incidental findings in the lumbar spine of pediatric patients : a study using magnetic resonance imaging as a screening tool. *Eur Spine J* 2016 ; 25 ; 596-601.
23. **Vanharanta H, Sachs BL, Spivey MA,** *et al.* The relationship of pain provocation to lumbar disc deterioration as seen by CT/discography. *Spine* (Phila Pa 1976) 1987 ; 12 : 295-8.
24. **Walsh TR, Weinstein JN, Spratt KF, Lehmann TR, Aprill C, Sayre H.** Lumbar discography in normal subjects. A controlled, prospective study. *J Bone Joint Surg Am* 1990 ; 72 : 1081-8.
25. **Wang Y, Videman T, Niemelainen R, Battie MC.** Quantitative measures of modic changes in lumbar spine magnetic resonance imaging: intra- and inter-rater reliability. *Spine* (Phila Pa 1976) 2011 ; 36 : 1236-43.
26. **Wang ZX, Hu YG.** [Clinical investigation of high-intensity zone in anterior annulus fibrosus of lumbar disc: compared with high-intensity zone in posterior annulus fibrosus]. *Zhonghua Wai Ke Za Zhi* 2009 ; 47 : 689-92.
27. **Wang ZX, Hu YG.** 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). *Eur Spine J* 2012 ; 21 : 1311-5.