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요추 추간판 탈출증 환자에서 발생 분절에 따른 디스크 탈출 방향의 차이

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2019 년 7 월

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Abstract

Differences in the location and migration patterns of herniated lumbar discs according to the disc level

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Background

Proper localization of a herniated disc fragment in both the horizontal and sagittal planes is important in planning the surgical approach and extent of exploration in the lumbar herniated intervertebral disc (HIVD). Few reports have investigated the sagittal location of lumbar herniated discs according to the disc level.

Objective

This study was aimed to investigate the differences in the location of HIVDs between the upper (L1-2 and L2-3) and lower lumbar spine (L4-5 & L5-S1) in the horizontal plane and sagittal plane.

Methods

The preoperative magnetic resonance imaging (MRI) data of 956 patients who underwent surgical procedures for a lumbar HIVD in the two affiliated hospital from January 2012 to December 2017 were retrospectively reviewed. Using the latest nomenclature and classification system, the location of the herniated discs and their migration patterns were classified by the horizontal plane and sagittal plane separately according to the affected levels.

Results

Fourteen, 40, 107, 508, and 287 patients with HIVD were identified and reviewed for each lumbar level from L1-2 to L5-S1. The most frequent location of a lumbar HIVD in the horizontal plane was the paracentral zone, followed by the subarticular zone regardless of the level. The proportion of the herniated discs in the central and the paracentral zone were significantly higher in the lower lumbar spine, whereas more laterally located herniated discs were relatively more frequent in the upper lumbar spine. The mean age of the patients tended to increase as HIVDs located in the higher lumbar level and in the more laterally positioned zone in the horizontal plane. Upward migration was more frequent in an upper lumbar HIVD, whereas downward migration was more frequent in a lower lumbar HIVD with statistical significance. Age, disc level, and the location in the horizontal plane were independently associated with upward migration.

Conclusion

The patterns of migration in both the horizontal and sagittal plane in an upper lumbar HIVD differed from those in a lower lumbar HIVD, which necessitated the different surgical approaches in select cases. The difference in the anatomical characteristics of lumbar vertebrae and biomechanical properties at each level may explain these results.

Keyword : Herniated intervertebral disc; lumbar disc herniation; upper lumbar disc; disc migration; disc migration pattern

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Introduction

In the surgical treatment of lumbar herniated intervertebral discs (HIVD), the identification of the affected level and the proper localization of the herniated disc in both the horizontal and sagittal plane are crucial pieces of information because they determine the surgical approach and extent.[1,2] Since 2003, one of the authors of this study performed a modified lateral laminectomy to access to the herniated discs in the upper lumbar levels (L1-2 & L2-3) with an impression that the upward migration of a herniated disc was more frequently seen in patients with an upper lumbar HIVD. Surprisingly, only a few previous studies have reported on the location and direction of a HIVD.[1–7] However, many of these studies had some limitations, such as a small sample number to draw a convincing outcome or a lack of description of migrated discs in the sagittal plane. Therefore, we retrospectively reviewed many patients from two affiliated institutes to investigate the migration patterns and differences in the locations of HIVDs in both the horizontal and sagittal plane according to the affected lumbar levels.

Materials and Methods

This study was approved by the Seoul National University Hospital and Seoul National University Bundang Hospital Institutional Review Board (H-1903-166-1023, B-1307/210-107). Using the electronic medical record system, patients who underwent surgery for a lumbar HIVD from January 2012 to December 2017 at the neurosurgical department of Seoul National University Hospital (SNUH) and Seoul National University Bundang Hospital (SNUBH) were retrospectively searched. In total, 1252 patients were surgically treated for the lumbar HIVD during that period.

Among these patients, 296 were eventually excluded, and 956 patients were reviewed for the study (Figure 1). The exclusion criteria were as follows: 1) a history of previous surgery on the affected level; 2) a ‘broad-based’ or ‘diffuse-bulging’ type of disc herniation; 3) no available magnetic resonance (MR) images.

The MR images of these patients were retrospectively reviewed, and the locations of the herniated discs were described according to the latest nomenclature and classification systems recommended by a multispecialty task force in 2014.[8] Briefly, ‘herniation’ is defined as ‘a localized displacement of disc material beyond the limits of the intervertebral disc space and includes both protrusion and extrusion’.

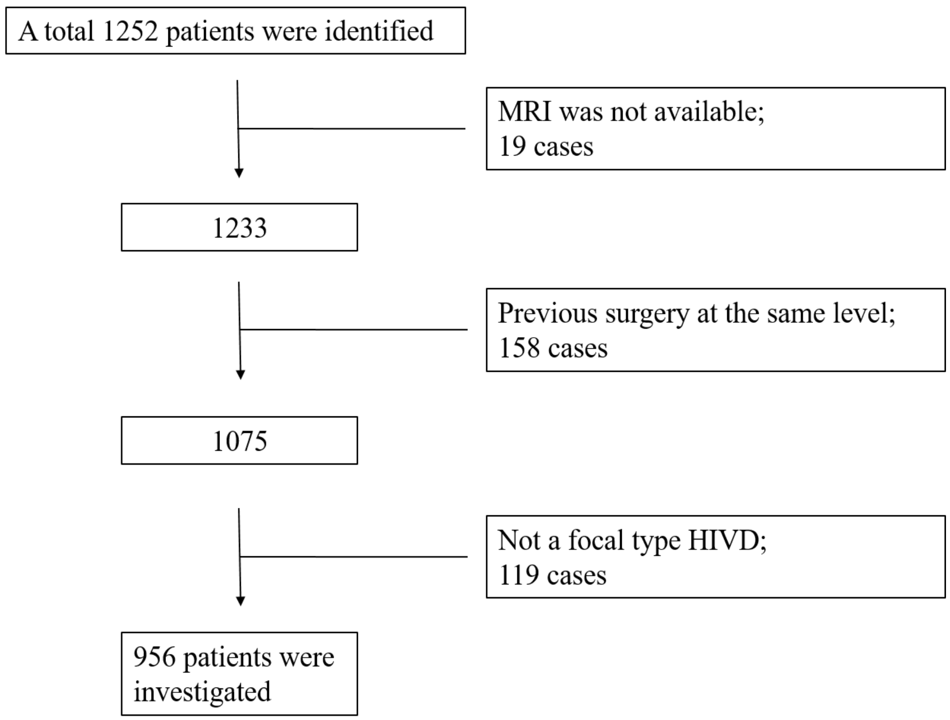

Figure 1. Flow diagram depicting patient selection. (MRI, magnetic resonance imaging, HIVD, herniated intervertebral disc)

The protrusion is defined if the greatest distance between the edges of the disc material presenting outside the disc space is less than the distance between the edges of the base of that disc material extending outside the disc space. Extrusion is defined when any one distance between the edges of the disc material beyond the disc space in at least one plane or disc material is sequestered. The horizontal location of the herniated disc is categorized as central zone, subarticular zone, foraminal zone, and extraforaminal zone from the central to the lateral direction, and the medial edges of the articular facets and medial and lateral borders of the pedicles define the boundaries on the horizontal plane.[8,9] The central zone is divided into the central zone, and right/left central zone, which used to be referred to as the paracentral zone.[8] (Figure 2) The term 'paracentral' zone is used in this study to simply describe the right/left central zone because the laterality of HIVDs is not a primary subject.

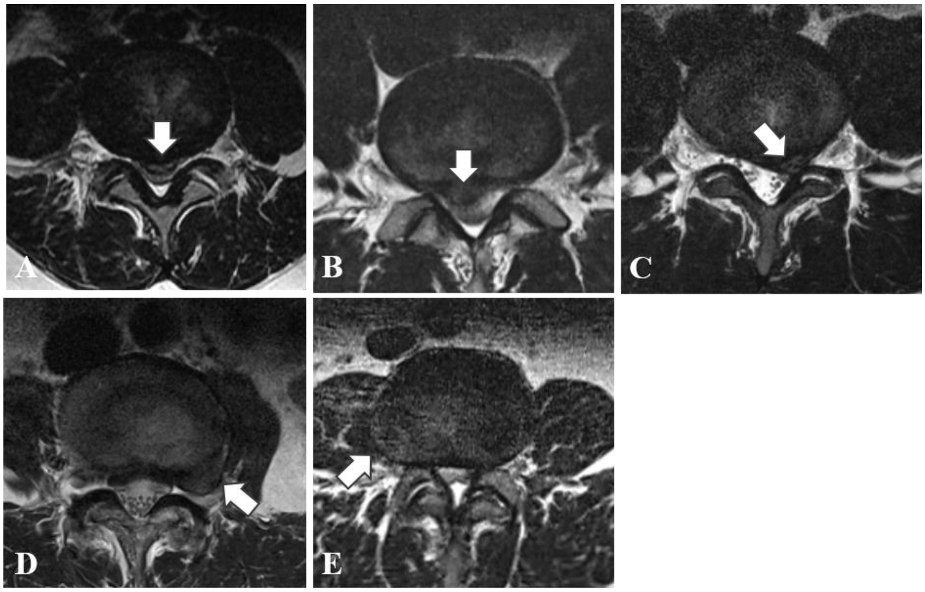

Figure 2. Axial MR images showing the location of HIVDs in the horizontal plane: A disc herniation (arrows) in the central (A), paracentral (B), subarticular (C), foraminal (D), and extraforaminal (E) zone.

The direction of migration in the sagittal plane is classified as disc level, upward migration, downward migration, and bidirectional migration.[2] (Figure 3) ‘Migration’ is defined as ‘displacement of disc material away from the site of extrusion, regardless of whether sequestrated or not.’ The degree of disc migration in the sagittal plane is presented according to the conventional system graded as the disc level, infrapedicular level, pedicular level, and suprapedicular level by the disc and the upper and lower borders of the pedicles.[8,9] Only the level in which surgery was performed was investigated.

Figure 3. Sagittal magnetic resonance images showing the direction of migration in the sagittal plane: disc level (A), upward migration (B), downward migration(C), and bidirectional migration (D)

For the statistical analysis, Student’s t-test, one-way ANOVA, and the Kruskal-Wallis test/ Mann-Whitney U test with post hoc analysis were used according to the variables’ characteristics. Chi-square statistics and linear by linear association were used to compare contingency table data. Logistic regression analysis was performed to verify independently associated factors. Age, gender, affected level (L1-3 *vs*. L3-S1), laterality of HIVDs (central/left/right), and the location in the horizontal plane (central/paracentral/subarticular/foraminal/extraforaminal zone) were assessed as variables. A *p*-value of less than 0.05 was considered statistically significant. Statistical analysis was conducted using SPSS version 22 (IBM Co., New York, NY, USA).

Results

Patients' characteristics

The study population included 533 (55.8%) male and 423 (44.2%) female patients, and the overall mean age was 49.6±16.3 years. The number of patients with the disc extrusion was 812 (84.9%), and the protrusion was 144 (15.1%). A total of 54 patients (5.7%) with upper lumbar HIVD (L1-2 & L2-3) were identified. The mean age of the patients with a HIVD at higher lumbar level tended to increase; The mean age of the patients was 66.2±11.6 years for L1-2 HIVD, 65.2±13.4 years for L2-3 (65.5±12.9 years for overall upper lumbar HIVD), 59.6±16.2 years for L3-4, 48.1±15.9 years for L4-5, and 45.6±14.5 years for L5-S1. The mean age of patients with HIVD in the upper lumbar level was significantly higher than that of patients with L4-5, or L5-S1 HIVD ($p<0.001$ for both). However, there was no significant difference from the patients with L3-4 HIVD. The patients' demographic data and characteristics are summarized in Table 1.

Disc migration in the horizontal plane

The locations of herniated discs in the horizontal planes are summarized in Table 2. Overall, the paracentral zone was the most common location of disc herniation, accounting for 57.9% of the cases, followed by the subarticular zone with 19.8%,

Table 1.

Demographic data of the study population and the characteristics of HIVDs.

Characteristics	**Number of patients**
Patients	956
Gender	
Mail	533 (55.8%)
Female	423 (44.2%)
Age (years)	49.6 ± 16.3
Level of HIVD*	
L1-L2	14 (1.5%)
L2-L3	40 (4.2%)
L3-L4	107 (11.2%)
L4-L5	508 (53.1%)
L5-S1	287 (30.0%)
Herniation type	
Protrusion	144 (15.1%)
Extrusion	812 (84.9%)
Surgical Method	
Microscopic	622 (65.1%)
Endoscopic	317 (33.2%)
Fusion	17 (1.8%)

the central zone with 15.4%, and the foraminal zone with 6.3%. The extraforaminal zone comprised the least proportion, 0.6%. Regardless of the level, the paracentral zone was the most common location of disc herniation. When the HIVDs was divided into the centrally located (HIVDs in the central and paracentral zone) and the laterally located ones (HIVDs in the subarticular, foraminal, and extraforaminal zone), the laterally located HIVDs were significantly more frequent in the upper lumbar level (*p*=0.036, Figure 4). The average age of patients tended to increase as the HIVDs occurred at more lateral side with the exception of the extraforaminal zone. The difference in age was statistically significant between the central zone (including paracentral zone) HIVDs, subarticular zone HIVDs, and foraminal zone HIVDs ($p<0.01$). The distribution of herniated discs on the right and left side were 437 (54.1%) and 371 (45.9%) respectively. This right-side dominance was observed at all levels.

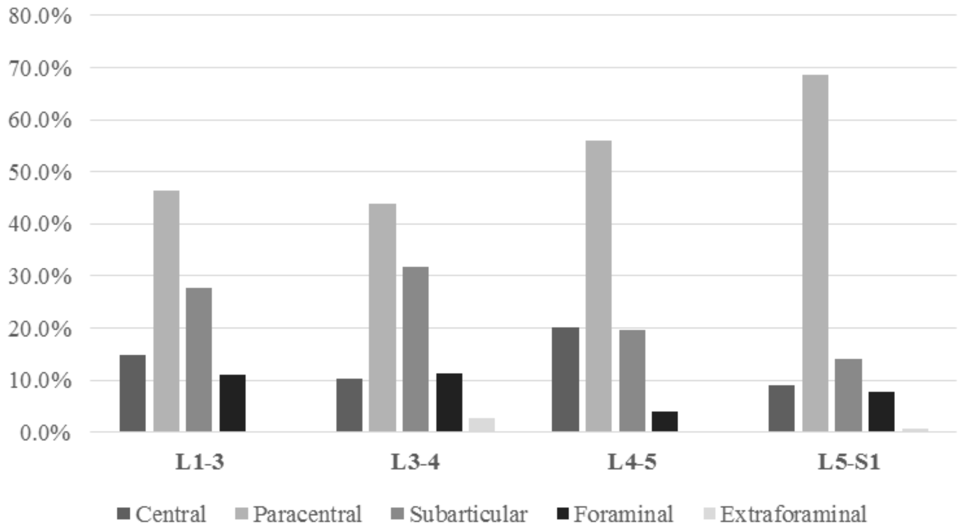

Figure 4. The proportion of HIVDs according to disc location in the horizontal plane in each level.

Disc migration in the sagittal plane

The overall frequency of “upward,” “disc level,” “downward,” and “bidirectional” migration was 16.5%, 30.2%, 50.4%, and 2.8%, respectively. The ‘upward’ migration was the most common at the upper lumbar level (L1-2 and L2-3), whereas ‘downward’ migration was dominant at the other levels (Figure 5).

Frequency of the upward migration in the upper lumbar level was significantly higher compared to L4-5 or L5-S1 level (p <0.001 for both). However, the difference between the upper lumbar levels and L3-4 did not reach statistical significance (p=0.762). The location of HIVDs in the sagittal plane at each level is presented in Table 3. In the case of 'upward' migration, the infrapedicular level was the most common location (69.0%), irrespective of the affected disc level. In the case of 'downward' migration, the pedicular level was the most frequent (45.3%) throughout the lumbar spine except L5-S1 level. The mean age of the patients with 'upward' migration was 57.6±16.5 years, and it was significantly higher than that of the patients with 'disc level' or 'downward' migration (46.4±16.4 and 48.7±15.3 respectively, p <0.001 for both). Based on logistic regression analysis, the upper lumbar levels (p=0.003, exp B=2.660; 1.388~5.098), age (p=0.005, exp B=1.019; 1.006~1.032), and locations in the horizontal plane (the subarticular zone, p=0.05, exp B=2.000; 0.999~4.003, the foraminal zone, p<0.001, exp B=19.003; 8.246~43.791 compared to the central zone) were independently associated with upward migration.

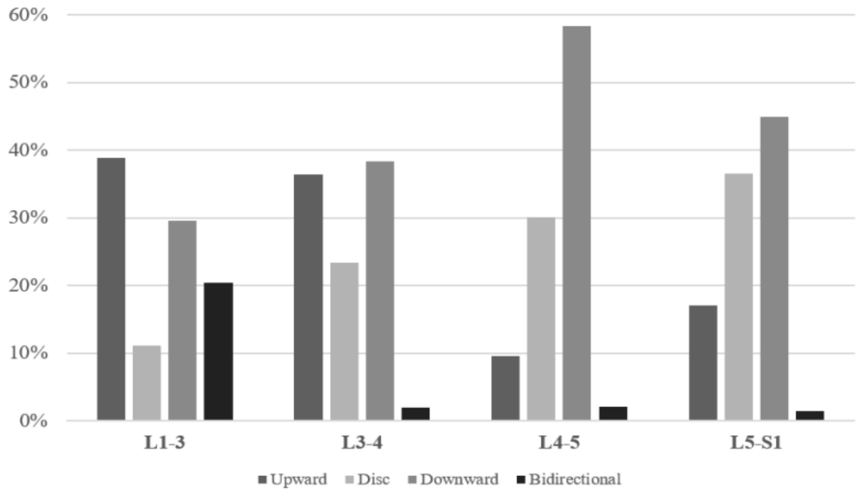

Figure 5. The direction of disc migration in the sagittal plane according to the affected level.

Table 2. The location of herniated discs in the horizontal plane according to the affected level.

	Location of herniated discs in the horizontal plane					
	Central	**Paracentral**	**Subarticular**	**Foraminal**	**Extraforaminal**	
L1-2	3	6	3	2	0	14
L2-3	5	19	12	4	0	40
L3-4	11	47	34	12	3	107
L4-5	102	285	100	20	1	508
L5-S1	26	197	40	22	2	287
Total	147 (15.4%)	554 (57.9%)	189 (19.8%)	60 (6.3%)	6 (0.6%)	956
Mean age*	44.9±16.2	47.1±15.5	55.2±16.0	65.8±10.1	61.5±6.1	

*The values represent the mean ± the standard deviation.

Table 3. The degree and the grade of herniated discs in the sagittal plane

		L1-2	L2-3	L3-4	L4-5	L5-S1	
Upward migration	Suprapedicular	0	1	0	5	4	10 (1.1%)
	Pedicular	1	4	13	10	11	39 (4.2%)
	Infrapedicular	3	12	26	35	34	110 (11.9%)
	Disc level	3	3	25	152	105	288 (31.1%)
Downward migration	Suprapedicular	1	1	6	127	59	194 (20.9%)
	Pedicular	2	8	25	134	49	218 (23.5%)
	Infrapedicular	0	4	10	35	21	70 (7.6%)

*Twenty-seven cases of the bidirectional migration were not included

Discussion

In the present study, the overall incidence of herniated discs was 1.5% at L1-2, 4.2% at L2-3, 11.2% at L3-4, 53.1% at L4-5, and 30.0% at L5-S1, and this order of frequency was the same as that in previously reported studies.[1,7] The central zone, more specifically the paracentral zone, was the most common location of herniated discs in the horizontal plane, and the occurrence of disc herniation tended to decrease as it occurred more laterally. In the horizontal plane, the mean age of patients tended to increase as HIVDs occurred in the more laterally positioned zone. In the sagittal plane, downward migration was most frequently found. However, the frequency of upward migration was significantly higher in the upper lumbar HIVDs (L1-2 & L2-3) compared to the lower lumbar HIVDs.

Although HIVD is one of the most common diseases of the lumbar spine, only limited data are available regarding the disc herniation pattern. Most of the reported data have come from the old CT era or small case series.[2–6] In 2016, Daghighi et al. reported a study regarding the lumbar disc migration pattern that is probably the largest case series comprising 1020 patients.[7]. Notably, they studied all the symptomatic patients consecutively who were diagnosed with a disc extrusion, regardless of the treatment. Similar to our result, they also reported that paracentral herniation occurred the most frequently in the horizontal zone with a higher incidence rate of upward migration at the upper lumbar levels.

Location in the horizontal plane

In this study, the locations of HIVDs in the horizontal plane were 15.4% in the central zone, 57.9% in the paracentral zone, 19.8% in the subarticular zone, 6.3%

in the foraminal zone, and 0.6% in the extraforaminal zone. There are not many reports describing the location of herniated discs in the horizontal plane. Daghighi et al. reported 4.3% and 2.5% of incident rate for the subarticular and foraminal HIVD respectively. Compared to those, the proportion of the subarticular and foraminal HIVD in this study is significantly higher. Probably this discrepancy might have resulted from the difference of study population; Our study comprises only surgically treated patients, whereas the previous one investigated consecutively collected patients who were newly diagnosed with HIVD regardless of treatment. Considering that radiculopathy is more likely to occur by the subarticular or foraminal HIVD than the central HIVD,[7] more patients with subarticular or foraminal HIVD might have taken surgical treatments, and this might have resulted in the higher incidence rate in this study.

A tendency of the increased mean age of patients who were treated for more laterally occurred HIVD is noteworthy. It might be related to degenerative changes in the spine.[10] The posterior longitudinal ligament and the epidural membrane have been regarded as the anatomical barriers for herniated disc fragment to migrate in the horizontal plane.[10,11] Anatomical changes according to the aging, like bone spur formation, disc degeneration, and coronal angulation, might cause environmental changes to those structures and result in the differences in the distribution of HIVDs in the horizontal plane. This result, however, does not coincide with a previously reported outcome, which reports the least mean age with the foraminal zone HIVD.[7] Accumulation of more evidence and further biomechanical study are required to clarify this result and elucidate exact mechanisms.

Interestingly, right side disc herniations were dominant, regardless of the levels in this study. It was not known yet whether it is an error from a limited number of samples or whether it is related to any physiologic factor, such as the dominance of right-handedness.

Location in the sagittal plane

In the present study, upward migration was more frequently found in the upper lumbar level (L1-2 & L2-3), while downward migration was more frequently seen in the lower lumbar spine. Previously, a handful of authors reported similar results.[7,12] Daghighi et al. reported 53.0% of upward migration in the upper lumbar spine and only 24.1% in the lower lumbar spine (L4-S1).[7] As with our results, they also suggested age as a risk factor for upward migration. Ahn et al. reported 61.9% and 42.2% of the upward migration rate in L1-4 and L4-S1, respectively.[12] In this study, the position of HIVDs in the horizontal plane (subarticular and foraminal zone) was also independently associated with upward migration as well. Several anatomical factors may contribute to the results. The herniated disc fragment may tend to migrate in a direction with low surrounding pressure physically. Therefore, if there were differences in the anteroposterior and cross-sectional diameters of the spinal canal across spinal levels, such anatomical difference might explain our finding. Interestingly, the study of Panjabi et al. indicated that the anteroposterior depth of the spinal canal decreased from L1 to L3 and then increased again from L3 to L5, so that the narrowest portion in the sagittal plane occurred at L3.[13] Additionally, the cross-sectional area of the spinal canal decreased from L1 to L2, remained constant from L2 to L4, and increased at L5. Thus, it could be speculated that herniated discs in the upper lumbar level tend to migrate cephalad, where there is a wider space ensuring less pressure, and herniated discs tend to move downward in the lower lumbar level for the same reason. The higher occurrence of upward migration in the foraminal zone might be explained in a similar hypothesis. Anatomically, the subpedicular area (where an upward migration could develop) bordered by the pedicle of cephalad vertebra is more spacious than the suprapedicular area (where a downward migration could develop) limited by the pedicle of the caudal vertebra. Ohshima et al. reported that the size of the posterior longitudinal ligament (PLL) diminishes significantly, and its attachment is relatively loose at lower lumbar levels.[14] This anatomical characteristic could explain the more frequent occurrence of vertical migration of a herniated disc in the upper lumbar spine. A herniated disc tends to migrate vertically confined by the PLL in the upper lumbar spine where broader and more solidly attached PLL is present. In the lower lumbar spine, a disc fragment is more likely to herniate out with PLL displacement or disruption. [13] Apart from these, the distribution of intervertebral stress, which might be closely related to the degree of lordosis or curve type, was raised as factors affecting disc migration patterns.[15,16] Bae et al. reported that patient with upper lumbar HIVD tended to have significantly shorter lumbar lordosis and long thoracic kyphosis with low pelvic incidence.[17] A more kyphotic shape of disc space in the upper lumbar spine in this population was prone to mechanical stress inducing herniation in the direction of the spinal canal.

Implications for surgical treatment

Some studies have demonstrated that the upper lumbar region has different anatomical features than the lower lumbar region regarding the relationship among disc space, laminar dimension, and facet joints.[18,19] The distance from the inferior border of the vertebral body (superior border of the disc space) to the superior edge of the inferior facet is short, which indicates that the facet joint is located inferior to the disc space in the sagittal plane. Therefore, the intervertebral disc space is barely covered by the facet joint due to its inferomedial location and small size. Because of these distinctive anatomical features, the conventional standard approach, represented by hemilaminectomy and medial facetectomy, requires more cephalad and extensive laminectomy to the isthmus and facet joint to secure appropriate surgical exposure of the herniated disc fragment. Additionally, the small and slender shape of the lamina in the upper lumbar spine can eventually lead to postoperative instability. Several reports have documented that the surgical outcome of the upper lumbar HIVD was not as good as that of the lower lumbar HIVD.[20–22] Given the results that there is a relatively high frequency of upward migration in the upper lumbar spine, these anatomical features would be more problematic. Several modified approaches have been introduced to overcome this problem, including the transfacetal approach, retroperitoneal approach, and other modified approaches.[20,23–25] One of the authors of the present study developed a technique, the paraspinal lateral laminectomy and discectomy (PLLD), and has applied it to clinical practice in cases of upper lumbar HIVD (figure 3). By removal of the lateral part of the lamina and upper inner part of the facet joint through a tube retractor, disc space and herniated fragments were successfully exposed and removed (Details of this surgical approach will be presented in a separate article). Similar to this approach, Son et al. reported a keyhole laminotomy technique for upper lumbar HIVDs and presented a successful outcome.[26] Except for the extent of bone removal on the lamina, this approach shares the same concept with PLLD. Recently, anatomical and clinical differences of upper lumbar HIVDs has also been recognized in the field of endoscopic surgery for HIVDs.[1,12,27] Given the high frequency of upward migration in the upper lumbar spine, these modified surgical approaches are worth to consider regardless of surgical modality.

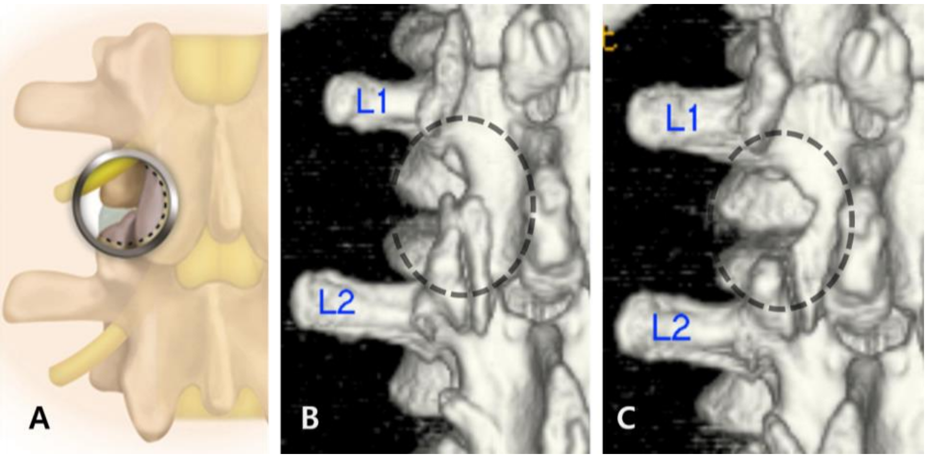

Figure 6. (A) Schematic illustration showing PLLD approach through the tubular retractor. (B, C) Pre- and post-operative 3D reconstructed CT images, showing the extent of the laminectomy and facetectomy. Note that disc level is exposed with the lateral laminectomy.

Limitations

Although this study is one of the largest series reporting disc herniation patterns, a few limitations exist. First, the study population comprised of a single ethnicity and race with a traditional sedentary lifestyle. Therefore, it is unclear whether our results could be applied to the general population with different cultures. Second, the factors associated with the direction of disc herniation discussed above have not been biomechanically proven yet; scant anatomical and biomechanical evidence supports this reasoning. Additional studies are necessary to improve the reliability of this result. Nevertheless, this study is valuable because it is one of the largest series describing the specific location of HIVDs, and presents the difference in the disc herniation pattern according to the affected level and age.

Conclusion

Recognizing the direction of disc herniation is crucial for symptomatic correlation and surgical approach. With accumulated evidence, it appears to have become evident that the migration patterns of herniated discs in the upper lumbar spine differ from those in the lower lumbar spine, especially in the sagittal plane. Although upper lumbar HIVDs are quite rare, these unique migration patterns should be considered in every step of the evaluation and surgical planning for a favorable outcome. Additional biomechanical and physiological studies are warranted to elucidate the precise mechanisms and causes of the difference.

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국문초록

요추 추간판 탈출증 환자에서 발생 분절에 따른 디스크 탈출 방향의 차이

배경

요추 추간판 탈출증 환자에서 탈출된 추간판의 위치를 수평면 및 시상면에서 정확히 특정하는 것은 수술적 치료의 방법을 계획하는데 매우 중요함에도 불구하고, 각각의 요추 분절에 따른 추간판 탈출증 양상의 차이를 다룬 연구는 드물다.

목적

각각의 요추 분절에 따라 수평면 및 시상면에서 추간판 탈출의 위치 및 방향의 차이가 있는지 확인하고, 이에 영향을 미치는 요인을 고찰한다.

대상 및 방법

2012년부터 2017년까지 추간판 탈출증으로 진단받고 디스크 제거수술을 시행받은 956명의 환자의 수술 전 자기공명영상(MRI)을 후향적으로 검토하고, 최신의 분류법에 따라 수평면 및 시상면에서의 위치를 특정하였다.

결과

요추 1-2번 분절부터 요천추 분절(L5-S1)까지 각각 14명, 40명, 107명, 508명, 287명의 환자에서 추간판 탈출증이 확인되었다. 수평면에서는 분절에 상관 없이 paracentral zone에 위치한 추간판 탈출증이 가장 흔하였고, subarticular zone에 위치한 추간한 탈출증이 뒤를 이었다. Central zone과 paracentral zone에 위치한 추간판 탈출증은 하부 요추(L3-S1)에서 발생 빈도가 높았고, 이보다 외측에 위치한 추간판 탈출

증은 상부 요추(L1−3)에서 더 빈번하게 발생하였다. 상부 요추에서는 디스크의 상방 이동(upward migration)의 발생 빈도가 높았고, 하부 요추에서는 하방 이동(downward migration)의 빈도가 유의하게 높았다. 환자의 나이, 이환된 요추 분절, 그리고 수평면에서의 탈출 위치가 디스크의 상방 이동과 독립적으로 관련이 있었다.

결론

상부 요추에서 추간판 탈출이 발생하는 방향은 수평면 및 시상면 모두에서 하부요추와는 차이를 보였으며 디스크 레벨 뿐만 아니라 나이도 독립적인 영향을 미쳤다. 환자를 평가하고 수술적인 치료를 계획하는데 이러한 차이들을 고려할 필요가 있다.

주요어: 요추 추간판 탈출증, 요추 수핵 탈출증

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