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대한영상의학회지

Multidetector CT Findings of Acquired Spondylolysis and Spondylolisthesis after Posterior Lumbar Laminectomy

요추 후방 감압술에서 발생한 후천적 척추분리증과 척추전방전위증의 다중검출 전산화단층촬영 소견

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Purpose We aimed to analyze postoperative multidetector CT (MDCT) of acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy.

Materials and Methods We enrolled 74 patients, from 2003 to 2017, who underwent posterior lumbar laminectomy with both pre and postoperative MDCT. The patients were categorized into the following two groups: group 1 without fusion and group 2 with fusion. We analyzed laminectomy width, level and location of spondylolysis or spondylolisthesis, facet changes, and fatty infiltration of paraspinal muscles on postoperative MDCT.

Results Incidence of spondylolysis or spondylolisthesis was 4 of 20 patients in group 1 and 2 of 54 patients in group 2. The laminectomy width (%) was defined as the percentage of the width of laminectomy to total lamina length. Mean laminectomy width (%) in patients with spondylolysis or spondylolisthesis was 54.0 in group 1 and 53.2 in group 2, in contrast to that in patients without spondylolysis or spondylolisthesis, which was 35.0 in group 1. The spondylolysis was observed at the level of the laminectomy and below pars interarticularis in group 1 and below the fusion mass at isthmic region in group 2.

Conclusion MDCT facilitates the diagnosis of postsurgical acquired spondylolysis and spondylolisthesis and demonstrates typical location of spondylolysis. Greater laminectomy width has been associated with occurrence of acquired spondylolysis and spondylolisthesis.

Index terms Spondylolysis; Spondylolisthesis; Multidetector Computed Tomography; Lumbar Vertebrae; Postoperative Complications

INTRODUCTION

Congenital or isthmic spondylolysis can be defined as a defect in the pars interarticularis of the vertebral arch. This defect is seen in radiographic studies and may either occur asymptomatically or be associated with significant low back pain (1). Spondylolysis is found predominantly at the level of L5. Spondylolisthesis is defined by the forward displacement of one vertebral body to the one subjacent to it and may be associated with spondylolysis.

However, little is known about the acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy, and only few reports have been published in this regard. To our knowledge, imaging analysis of multidetector CT (MDCT) in case of acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy has not been reported.

Therefore, the purpose of this study was to describe acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy. In addition, we demonstrate the postoperative MDCT findings of acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy and assess the causative factors of acquired spondylolysis and spondylolisthesis.

MATERIALS AND METHODS

STUDY SUBJECTS

The Institutional Review Board of the Ewha Womans University Mokdong Hospital approved this retrospective study and waived the requirement for informed consent owing to the retrospective design of the study (IRB No. SEUMC 2019-11-031).

From 2003 to 2017, 321 lumbar MDCT were performed before or after posterior lumbar laminectomy. We included 120 patients having both preoperative and postoperative MDCT. We excluded patients for the following reasons: 1) posterior decompression surgery due to malignancy such as metastasis or infection (n = 5) or 2) spondylolysis or spondylolisthesis on preoperative MDCT (n = 5) or 3) MDCT from outside hospital (n = 18) or 4) unknown type of surgery (n = 6) or 5) 2D axial image at disc level only (n = 12). Finally, 74 patients were enrolled in this study. The patients were classified into 2 groups according to whether they had undergone fusion surgery. There were 20 patients (27.0%) in group 1 who have had posterior lumbar laminectomy without fusion, and 54 patients (73.0%) in group 2 who have had posterior lumbar laminectomy with fusion. The mean age was 53.1 years (53.1 ± 15.9) in group 1 and, 62.2 years (62.3 ± 12.1) in group 2.

And we reviewed clinical and operation data of patients with spondylolysis or spondylolisthesis after posterior lumbar laminectomy. We analyzed age (year), body mass index (kg/m^2), preoperative diagnosis, type and level of surgery, and follow up duration (month).

IMAGING ACQUISITION AND ANALYSIS

Imaging protocols were as follows: postoperative lumbar spine MDCT was performed using MDCT equipment with 16 or 64-channel MDCT (SOMATOM Sensation 16 or 64; all from Siemens Medical Solutions, Erlangen, Germany). The acquisition parameters were as follows: tube voltage, 120 kVp; effective tube current, 250 mAs; collimation, 0.6 mm; slice thickness, 2 mm; pitch, 0.6; field of view, 120 mm × 120 mm. Coronal and sagittal reformatted images were obtained based on the axial images 2 mm slice thickness. Contrast agent was not used. MDCT images were obtained from T12 to S1 vertebral body.

MDCT images and radiologic reports were retrospectively reviewed by three radiologists with 3, 19, and 30 years of experience.

We compared width of laminectomy among each group. The width of laminectomy was measured on postoperative MDCT axial images. It was described as the percentage of the width of laminectomy to total lamina length (Fig. 1). Lamina is a broad plate which project backwards and medialwards to join from each pedicle and to anterior border of spinous process. The width of laminectomy was measured at the level of the maximum defect site. In case of bilateral laminectomy, the length of total lamina was defined as summation of the both lamina lengths, from the anterior border of spinous process to the both pedicles. In case of unilateral laminectomy, the length of total lamina was defined as the unilateral lamina length of operated side.

And we assessed whether acquired spondylolysis or spondylolisthesis may occur or not on postoperative MDCT. And we also analyzed the level and location of spondylolysis and spondylolisthesis in patients with spondylolysis and spondylolisthesis after posterior lumbar laminectomy with or without fusion. The location of spondylolysis was assessed in terms of whether it was located at the isthmic portion at pars interarticularis or below pars interarticularis and adjacent to the facet joint. The level (L1–L5) and side (right, left, both) of spondylolysis were also assessed. The level and degree of spondylolisthesis were assessed on sagittal MDCT images. The percentage of spondylolisthesis was calculated as the ratio of the distance between posterior margins of the adjacent vertebral body and the anteroposterior length of the lower vertebral body.

We analyzed facet joint changes such as subluxation and osteoarthritis on postoperative MDCT images as compared with preoperative MDCT. And fatty grade of paraspinal muscles were evaluated on MDCT images using Goutallier classification, ranging grade 0 (normal muscle), grade 1 (fatty streak), grade 2 (less fat than muscle), grade 3 (equal amounts of fat and muscle), grade 4 (more fat than muscle).

Fig. 1. Measurement of laminectomy width in patient demonstrating right partial laminectomy on axial multidetector CT. The width of laminectomy is measured at the level of the region depicting highest degree of defect (arrow line). Length of right lamina is measured from the anterior border of spinous process (dotted line) to the right pedicle (line). The percentage of the width of laminectomy is calculated as: (width of laminectomy)/(length of right lamina) × 100 (%).

RESULTS

In all cases of posterior lumbar laminectomy, whether with fusion or not, the incidence of acquired spondylolysis and spondylolisthesis was 6 of 74 patients (8.1%, mean age, 48.3 years) in this study. The incidence of spondylolysis and spondylolisthesis was 4 of 20 patients (20.0%) in group 1 without fusion, and 2 of 54 patients (3.7%) in group 2 with fusion (Fig. 2).

The clinical and operation data of the patients are briefly described in Table 1.

The width of laminectomy was summarized in Table 2. The mean width of laminectomy was 54.0% (22.6–70.2%) in cases with acquired spondylolysis and spondylolisthesis among group 1. In contrast, the mean width of laminectomy was 35.0% (20.8–66.4%) in cases without acquired spondylolysis nor spondylolisthesis among group 1. The mean width of laminectomy was 53.2% (34.8–75.9%) in cases with acquired spondylolysis and spondylolisthesis among group 2.

The location of acquired spondylolysis in group 1 was below the pars interarticularis and adjacent to the facet joint (Figs. 3, 4). In contrast, the location of acquired spondylolysis in group 2 was the isthmic portion at pars interarticularis (Fig. 5). The level of acquired spondy-

Fig. 2. Flow chart for selection of patients with acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy.
MDCT = multidetector CT

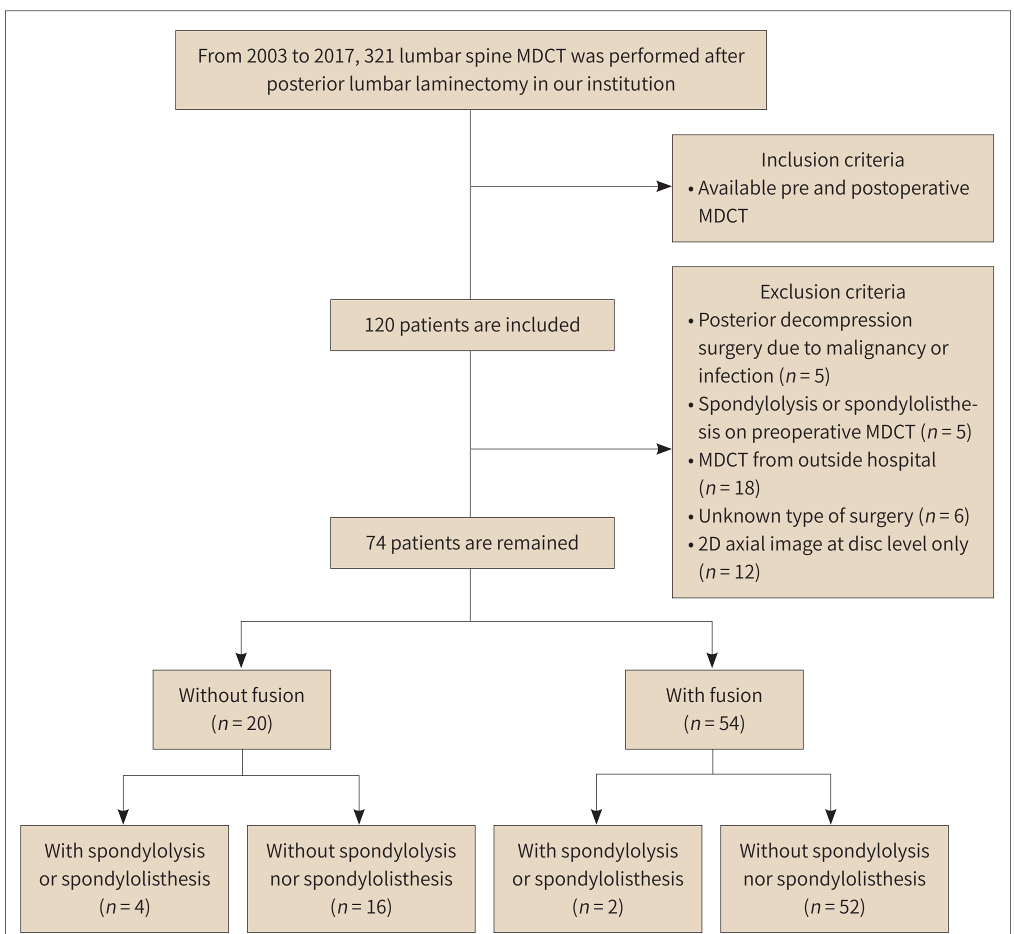


Table 1. Summary of Cases with Acquired Spondylolysis or Spondylolisthesis after Posterior Lumbar Laminectomy

Group	Case	Age (years)/ Sex	BMI (kg/m)	Preoperative Diagnosis	Type and Level of Surgery	Duration (months)
1	1	50/F	23.8	Disc protrusion, L3–4	Bilateral partial laminectomy, L3 without fusion	9
	2	46/F	26.6	Disc protrusion, L4–5	Bilateral partial laminectomy, L4 without fusion	20
	3	29/M	19.0	Disc protrusion, L3–4	Right partial laminectomy, L3 without fusion	6
	4	51/M	22.0	Disc bulging, L4–5	Left partial laminectomy, L4 without fusion	66
2	5	62/F	21.6	Disc protrusion, L3–4 and L5–S1 Disc extrusion, L4–5	Bilateral partial laminectomy and facetectomy, L4 and left partial laminectomy, L5 with PLIF, L4/L5 and PLF, L3–L5	22
	6	66/F	27.2	Disc protrusion, L4–5	Left partial laminectomy, L4 with PLIF, L4/L5 and PLF, L4–L5	140

Group 1 was included patients who have had posterior lumbar laminectomy without fusion, and Group 2 was included patients who have had posterior lumbar laminectomy with fusion.
BMI = body mass index, L = lumbar, PLF = posterolateral fusion, PLIF = posterior lumbar interbody fusion, S = sacral

Table 2. Multipledetector CT Findings in Cases of Acquired Spondylolysis or Spondylolisthesis after Posterior Lumbar Laminectomy

Group	Case	Level and Width of Laminectomy		Spondylolysis		Spondylolisthesis		Facet Joint Changes	Fatty Grade of Paraspinal Muscles
		Level	Width (%)	Level	Location	Level	Degree (%)		
1	1	Both L3	70.2	Both L3	F	L3–4	8.4	-	Grade 1
	2	Both L4	68.2	Both L4	F	L4–5	2.5	-	Grade 0
	3	Right L3	55.1	Right L3	F	-	-	-	Grade 0
	4	Left L4	22.6	Left L4	F	L4–5	7.4	Subluxation and OA	Grade 0
2	5	Both L4	75.9	-	-	-	-	-	Grade 2
		Left L5	34.8	Right L5	I	-	-	-	Grade 2
	6	Left L4	49.1	-	-	L3–4	6.4	Subluxation	Grade 2

Group 1 was included patients who have had posterior lumbar laminectomy without fusion, and Group 2 was included patients who have had posterior lumbar laminectomy with fusion.
F = below the pars interarticularis and adjacent to the facet joint, I = isthmic portion at pars interarticularis, L = lumbar, OA = osteoarthritis

lolysis in group 1 was found in the operated segment, being both and right L3 in 2 patients and both and left L4 in 2 patients. In contrast, it was below the fusion mass, being right L5 in group 2. Acquired spondylolisthesis was noted in 3 of 4 cases in group 1 and in 1 of 2 cases in group 2. The mean degree of spondylolisthesis was 6.2% (Table 2).

The facet joint changes such as subluxation and osteoarthritis were found in a case among group 1 and 2, respectively on postoperative MDCT. The paraspinal muscles were not changed after surgery and grade of fatty change was grade 0 in 3 cases, grade 1 in a case among group 1, and grade 2 in 2 cases among group 2 (Table 2).

DISCUSSION

Lumbar spinal stenosis is a common cause of low back pain (2, 3). Several factors, such as ligamentum flavum hypertrophy, facet joint hypertrophy, or disc herniation, can lead to lumbar spinal stenosis (2, 3). Posterior decompression is considered an important treatment for lumbar spinal stenosis (3, 4).

In case of symptomatic lumbar spinal stenosis without appropriate treatment by conservative therapy, facet-preserving laminectomy is the gold standard treatment (4). In total laminectomy, the entire width of a lamina is resected with the removal of thickened ligament flavum and hypertrophic facet joint, which are responsible for the compression of the overlying spinal nerve (5). In partial laminectomy, the partial lamina is removed, which may be unilat-

Fig. 3. A 50-year-old female patient with low back pain, 10 months after bilateral partial laminectomy at L3–4 (Case 1). Postoperative multidetector CT sagittal images show both acquired spondylolysis at L3 on right (first image) and left (second image) parasagittal images (arrows) and acquired spondylolisthesis at L3 on L4 on midsagittal image (third image) (arrowhead).

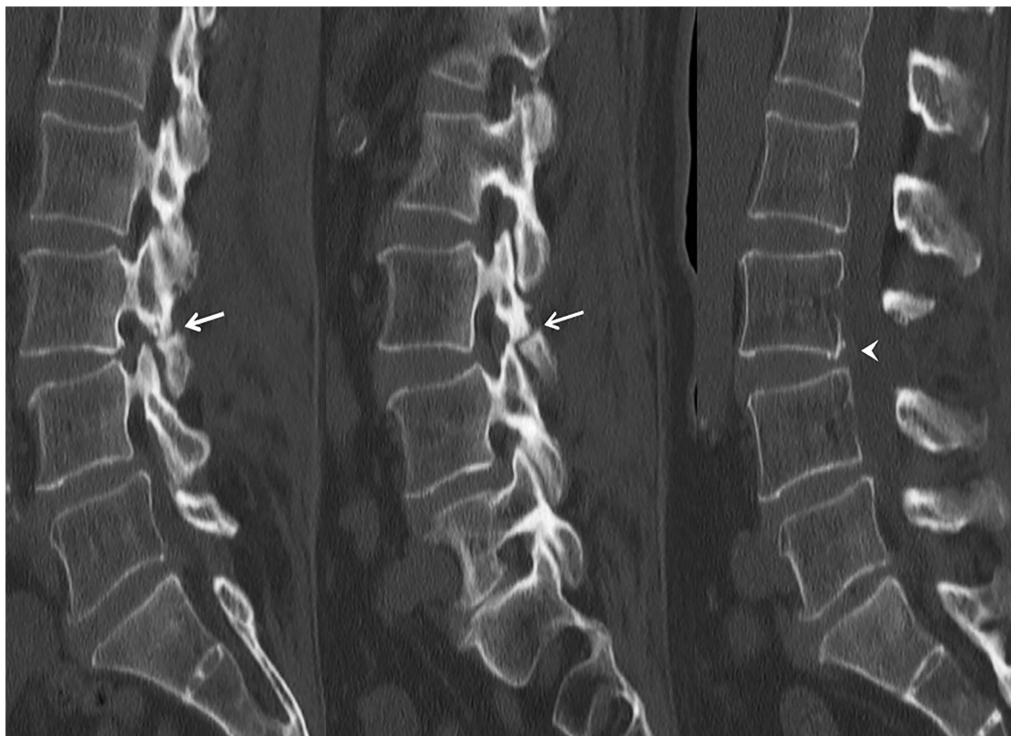


Fig. 4. A 29-year-old male patient with recurrent low back pain, 6 months after right partial laminectomy at L3–4 (Case 3). Postoperative multidetector CT parasagittal image (first image) and coronal image (second image) show spondylolysis (arrows) at right L3 without spondylolisthesis. The postoperative multidetector CT axial image (third image) shows the site of right partial laminectomy (asterisk) at L3.

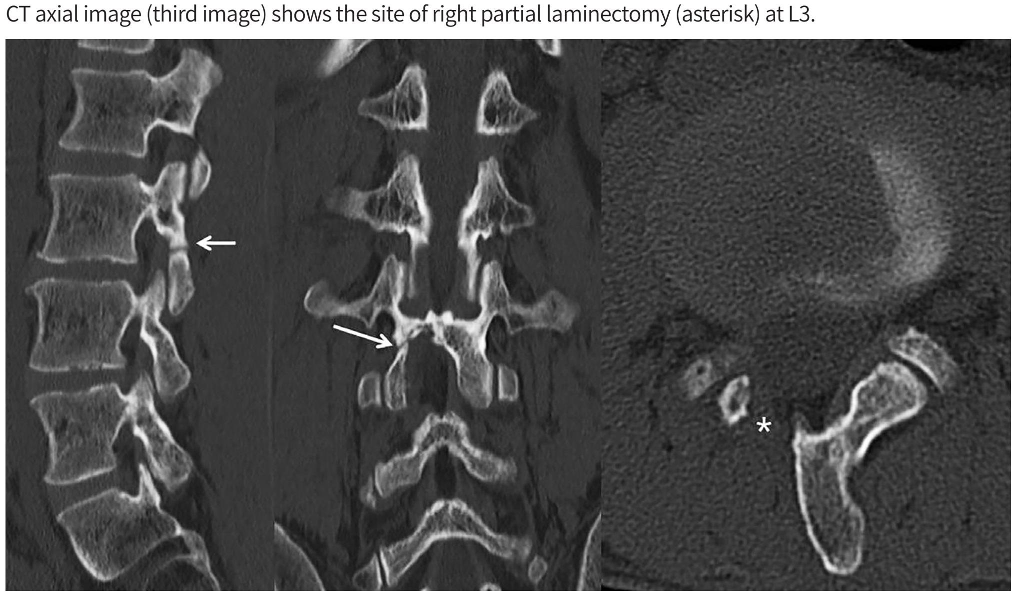
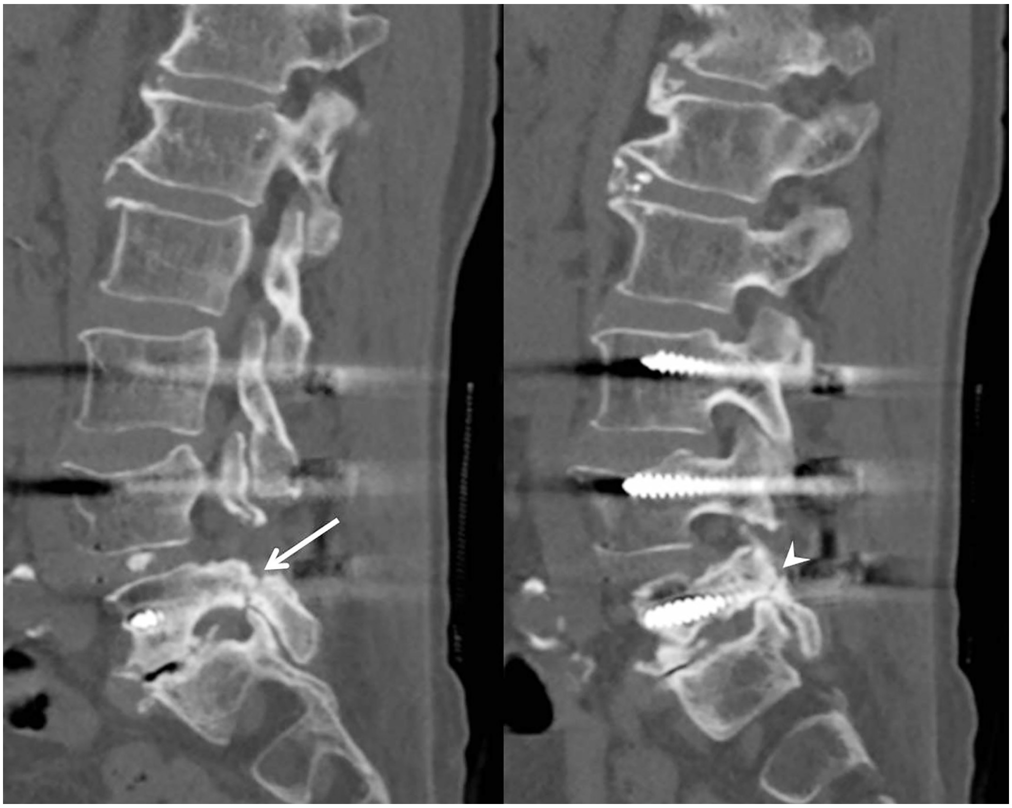


Fig. 5. A 60-year-old female patient with low back pain, 22 months after bilateral partial laminectomy and bilateral facetectomy at L4 and left partial laminectomy at L5 with posterior lumbar interbody fusion at L4–5 and posterolateral fusion at L3–5 (Case 5). Postoperative multidetector CT parasagittal images show acquired spondylolysis at right L5 that is located at pars interarticularis (first image, arrow) and below the fusion mass (second image, arrowhead).



eral or bilateral. For example, in en bloc partial laminectomy, the inferior half of bilateral lamina and spinous process are resected (6). Unilateral laminectomy is the removal of one side of lamina, which preserves the both facet joints and neural arch of the contralateral side, limits postoperative destabilization and protects the nervous structure against posterior scarring (7). In laminectomy and facetectomy, some or all of the apophyseal joint is resected with cephalic and caudal lamina to resolve foraminal or lateral recess stenosis (8). Patient with extensive decompression are recommended to be treated with spinal fusion, such as bilateral facetectomy over one-third or one-half of the facet, excision of more than half of the pars interarticularis, and bilateral discectomy with partial facetectomy (5).

Postoperative instability is a common complication after decompression surgery without fusion. Because of the lack of standard criteria, the incidence of posterior decompressive instability varies from 0% to 63% (9). There have been several studies about postoperative spinal spondylolisthesis (9-11). However, only few have reported about spondylolysis after posterior lumbar laminectomy without fusion (12, 13). Brunet and Wiley (14) reported fourteen cases of acquired spondylolysis occurring after posterior spinal fusion. In our study, the incidence of acquired spondylolysis and spondylolisthesis was 4 of 20 patients (20.0%) in group 1 and 2 of 54 patients (3.7%) in group 2. Acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy were slightly more likely to occur in cases without fusion than that with fusion.

In our study, the location of acquired spondylolysis differs from congenital spondylolysis. Four patients in group 1 was developed acquired spondylolysis at the below the pars interarticularis, and adjacent to the facet joint and laminectomy level. Similarly, Rothman et al. (15) reported 25 patients found to have fractures of the base of one or both inferior lumbar articular facets at the level of the laminectomy and facetectomy without fusion. The most plausible explanation for this was that the weakened articular process undergoes stress fracture when the patient returns to the upright position. This would explain the typical history of a period of well-being after the original surgery before symptoms recur. Hyperextension motions were expected to exert severe stress on the surgically weakened articular process. Once the facets break, the motion segment could sublux, thus leading to root entrapment. In contrast, in our study, 2 patients in group 2 was developed acquired spondylolysis at the isthmic portion and pars interarticularis and below the fusion mass. Brunet and Wiley (14) reported acquired spondylolysis occurring after posterior spinal fusion was thought to develop as a result of structural weakening of the pars interarticularis during operation, eventually followed by stress fractures induced by repeated torsional and bending stresses. The degeneration of the intervertebral disc above or below the fusion mass and damage to the posterior ligament complex might also contribute to the development of lesions by reducing the resistance to shearing forces at the intervertebral level next to the fusion. Therefore, acquired spondylolysis after posterior lumbar laminectomy with fusion might occur above or below the fusion mass and adjacent to pars interarticularis.

Suzuki et al. (13) tried the radiographic measurement of the decompression size using lumbar spine plain radiography and reported that the percentage of decompression width was 53% at the operation level in case of conventional laminectomy without fusion. In our study, the measurement of laminectomy width was done using MDCT images. It is more accurate than radiographic analysis. Based on MDCT results, the mean laminectomy width was 54% in patients with 6 acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy. In contrast, it was 35% in patients without acquired spondylolysis nor spondylolisthesis. These results show that extensive decompression can be a risk factor for acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy.

Our study had limitations of the small number of patients, because of which statistical analysis could not be performed. Therefore, further studies with a larger number of cases are warranted to help us find other causative factors.

In conclusion, acquired spondylolysis or spondylolisthesis after posterior lumbar laminectomy demonstrates typical location of spondylolysis different from that of congenital spondylolysis. Acquired spondylolysis after posterior lumbar laminectomy without fusion cases developed at the below the pars interarticularis and adjacent to the facet joint and laminectomy level. Conversely, acquired spondylolysis after posterior lumbar laminectomy with fusion developed at the isthmic portion and pars interarticularis and below the fusion mass. Large laminectomy width was a causative factor of acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy.

MDCT with multiplanar reconstruction is helpful to diagnose acquired spondylolysis and spondylolisthesis after posterior lumbar laminectomy, and the patients who are treated with more than 50% laminectomy should be followed up carefully using MDCT.

Author Contributions

Conceptualization, H.J.Y., Y.J.H.; data curation, all authors; formal analysis, H.J.Y., Y.H.; investigation, all authors; methodology, H.J.Y.; project administration, H.J.Y.; resources, Y.H.; software, H.J.Y., Y.H.; supervision, H.J.Y.; validation, H.J.Y., Y.H.; visualization, H.J.Y.; writing—original draft, H.J.Y., Y.H.; and writing—review & editing, H.J.Y., Y.J.H.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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요추 후방 감압술에서 발생한 후천적 척추분리증과 척추전방전위증의 다중검출 전산화단층촬영 소견

윤혜인[1] · 황지영[2,3]* · 유정현[1,3]

목적 이 연구는 요추 후방감압술에서 발생한 후천적 척추분리증과 척추전방전위증의 다중검출 전산화단층촬영 소견에 대해 분석하고자 하였다.

대상과 방법 2003년부터 2017년까지 요추 후방감압술을 시행 받고 수술 전 및 수술 후 다중검출 전산화단층촬영을 촬영한 74명의 환자를 대상으로 하였다. 유합술을 시행하지 않은 1군과 유합술을 시행한 2군의 환자로 분류하였다. 수술 후 다중검출 전산화단층촬영 영상에서 요추 후방감압술의 크기, 척추분리증 또는 척추전방전위증 유무와 위치, 척추전방전위증의 유무, 후방관절 및 척추주위 근육의 지방 변화에 대해 분석하였다.

결과 후천적 척추분리증 또는 척추전방전위증의 빈도는 1군에서 20명 중 4명, 2군에서 54명 중 2명이였다. 후방감압술의 크기(%)는 전체 추궁판에 대한 추궁절제술의 크기를 백분율로 계산하였다. 요추 후방감압술의 크기(%)는 후천적 척추분리증 또는 척추전방전위증이 있는 경우 54.0 (1군)과 53.2 (2군)이었고, 후천적 척추분리증과 척추전방전위증이 없는 경우는 35.0 (1군)이었다. 척추분리증의 위치는 1군에서는 후방감압술 분절의 후관절 부근에서 발생하며, 2군에서는 유합술 하방의 관절 간부에 발생하였다.

결론 다중검출 전산화단층촬영은 요추 후방감압술 이후 후천적 척추분리증과 척추전방전위증을 진단하는 데 유용하고, 후천적 척추분리증의 전형적인 위치를 잘 보여준다. 요추 후방감압술의 크기가 클수록 후천적 척추분리증과 척추전방전위증의 발생과 연관이 있었다.

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