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Clinical Article

Morphologic Changes of L5 Root at Coronal Source Images of MR Myelography in Cases of Foraminal or Extraforaminal Compression

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Objective : Two findings easily found at coronal source images of MR myelography (MRM) were evaluated : dorsal root ganglion (DRG) swelling and running course abnormality (RCA) of L5 exiting root at foramen or extraforamen. We tried to find the sensitivity of each finding when root was compressed.

Methods : From 2004 July to 2006, one hundred and ten patients underwent one side paraspinal decompression for their L5 root foraminal or extraforaminal compression at L5-S1 level. All kinds of conservative treatments failed to improve leg symptom for several months. Before surgery, MRI, CT and MRM were done. Retrospective radiologic analysis for their preoperative MRM coronal source images was done to specify root compression sites and L5 root morphologic changes.

Results : DRG swelling was found in 66 (60%) of 110 patients. DRG swelling has statistically valuable meaning in foraminal root compression (chi-square test, $p < 0.0001$). Seventy-two (66%) in 110 patients showed abnormal alteration of running course. Abnormal running course has statistically valuable meaning in foraminal or extraforaminal root compression (chi-square test, $p < 0.0001$).

Conclusion : Three-dimensional MRM provides precise thin sliced coronal images which are most close to real operative views. DRG swelling and running course abnormality of L5 exiting root are two useful findings in diagnosing L5 root compression at L5-S1 foramen or extraforamen. MRM is thought to provide additional diagnostic accuracy expecially in L5-S1 foraminal and extraforaminal area.

KEY WORDS : MR myelography · Foraminal or extraforaminal · Lumbar disc herniation.

INTRODUCTION

Anatomic studies of lumbar roots at foramen or extraforamen have been done by using human cadavers[3,6,13]. Pathologic changes such as proximal migration of dorsal root ganglion (DRG), running course abnormality (RCA) were documented but each of their clinical meaning was not proven in foraminal or extraforamial exiting root compression. We observed pathologic root morphology when exiting root is compressed at either foramen or extraforamen. DRG of exiting root usually exists within foramen and it is the most sensitive portion in relation to pain. Exiting root compressions at L5-S1 level have some meaning in that the length of exiting root from the start of foramen to the end of extraforaminal is longest at L5-S1 level than any other lumbar levels and exiting L5 root passes through long peculiar "lumbosacral tunnel"[8]. Various pathologic factors that cause radicular pain were found : foraminal stenosis by S1 superior facet impingement and foraminal narrowing, foraminal or extraforaminal disc herination, lumbosacral ligament impingement and so on[8,11]. Conventional myelography, CT or MRI are thought as enough to detect lesion in the spinal canal. Thin sliced coronal source images of magnetic resonance myelography (MRM) also have merits that they give view most close to operative field. Considering of the 3 dimensional direction of exiting root, we could get best images of DRG and trace to the end point of exiting root by observing thin sliced coronal MR views[15]. Two major findings in MRM coronal images were analyzed for their change according to compression site from foramen to

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extraforamen : swelling of DRG and RCA of L5 exiting root.

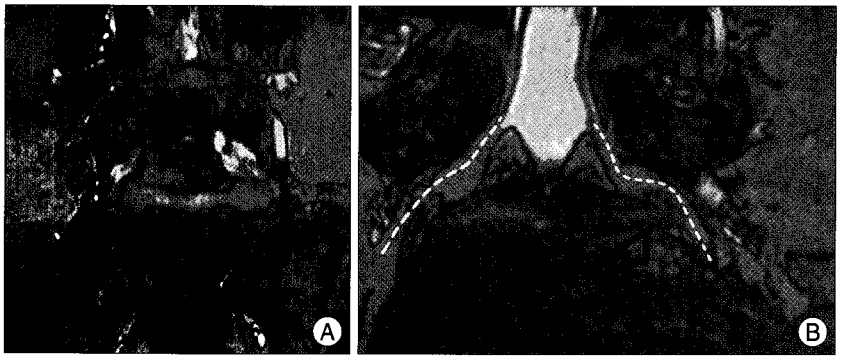

Fig. 1. A : Dorsal root ganglion swelling by foraminal disc hemiation. B : Running course abnormality of L5 at L5-S1. L5 root is impinged by extraforaminal disc.

MATERIALS AND METHODS

One-hundred-ten patients with foraminal or extraforaminal disc herniations at L5-S1 level were included in this study who underwent unilateral L5-S1 paraspinal decompression from 2004 July to 2006 June. They failed conservative therapy such as medication, physical therapy or root block for no more than 6 months. L5-S1 unilateral decompression and discectomy were done after excluding the diagnosis hip-spine syndrome, S-I joint problem, and piriformis syndrome. Patients' age ranged from 35 to 77 years and male to female ratio was about 1 : 2.23. Foraminal or extraforaminal lesions were confirmed by preoperative CT, MRI and MRM. We excluded the patients who had bilateral lesions or concomitant double crush lesion at L4-5 level. The first and second author each reviewed preoperative MRM twice. MRM was obtained on a 1.5 T MR unit (Intera, Philips Medical Systems, Eindhoven, the Netherlands). The parameters of a coronal 3D sequence were as follows : TR 4.96 ms, TE 2.16 ms, 1-mm-thick slices, matrix 336 × 336.

Exiting root compressing disc herniation was divided into foraminal, extraforaminal or mixed type. At L5-S1 disc level, there is no established definition of "foramen" because its outer margin is not clear owing to absence of outer margin of S1 pedicle. In this study, vertical line from outer margin of L5 pedicle was thought to be borderline between foramen and extraforamen. Foraminal disc herniation is defined as root compressing disc herniation which occurred only at foramen. Extraforaminal disc herniation is defined as L5-S1 disc herniation lateral to foramen without foraminal component. Exiting root is traced from foramen to its outermost end point, usually lateral margin of ala where L5 root wrap around the corner of S1 superior body and disappear into pelvic cavity.

DRG swelling was defined as positive when its size was bigger than other normal side (Fig. 1A). Running course of exiting root can be displaced cranially by foraminal disc or hypertrophied superior articular facet impingement. Extraforaminal disc herniation also can make sharp angulation of running course. So, we defined as abnormal if the running course altered by foraminal or extraforaminal disc (Fig. 1B). But, the running course was considered negative when there was small far lateral disc impingement on L5 root and no definite change of running course at the compressed site.

Interrater reliability for MRI interpretation of DRG swelling and RCA

Intraobserver variability

The same examiner studied 110 preoperative MRM twice. Values of the kappa coefficient for DRG swelling and RCA were more than 0.9 which means excellent agreement.

Interobserver variability

Two independent examiners evaluated same 110 MRMs. The kappa coefficient for DRG swelling was 0.89 and RCA, 0.96. Kappa value range from 0.81 to 1.00 means two examiners has excellent agreement.

RESULTS

Dorsal root ganglion swelling (Table 1)

DRG swelling was found in 66 (60%) of 110 patients. When distal portion of DRG was compressed by foraminal or extraforaminal disc, DRG swelling was observed. One patient who has had asymptomatic side DRG swelling showed delayed onset of leg pain after symptomatic side decompression. DRG swelling was observed whenever there was foraminal compression in 66 patients. DRG swelling was not observed when exiting root was compressed by extraforaminal disc alone (32 in 44). DRG was directly compressed by ruptured foraminal disc (12 in 44) and DRG swelling was recorded as negative in these cases. DRG swelling has statistically valuable meaning in foraminal root compression (chi-square test, $p < 0.0001$).

Running course abnormality (Table 2)

Seventy-two (66%) in 110 patients showed abnormal alteration of running course. It was negative when size of extraforaminal disc was not that much to influence alteration of running course or when DRG itself was directly impinged

Table 1. Incidence of DRG swelling in operated and normal side

DRG swelling	Swelling (%)	No swelling (%)	Total (%)
Operated side	66 (60.0)	44 (40.0)	110 (100.0)
Normal side	1 (0.9)	109 (99.1)	110 (100.0)
Sensitivity (TP / TP + FN) (%) = 60.0			
Specificity (TN / TN + FP) (%) = 99.1			
Positive predictive value (%) = 98.5			
Negative predictive value (%) = 71.2			

DRG : dorsal root ganglion

Table 2. Presence of RCA in operated and normal side

RCA	RCA (%)	No RCA (%)	Total (%)
Operated side	72 (65.5)	38 (34.5)	110 (100.0)
Normal side	4 (3.6)	106 (96.4)	110 (100.0)
Sensitivity (TP / TP + FN) (%) = 65.5			
Specificity (TN / TN + FP) (%) = 96.4			
Positive predictive value (%) = 94.7			
Negative predictive value (%) = 73.6			

RCA : running course abnormality

by disc just under L5 pedicle. In 4 cases, patient was symptom free even though running course was abnormal by extraforaminal herniated disc presence. Abnormal running course had statistically valuable meaning in foraminal or extraforaminal root compression (chi-square test, $p < 0.0001$).

DISCUSSION

The diagnosis of foraminal or extraforaminal disc herniation was very difficult before MRI and MRM were commonly used. Discography-CT was once used to identify extraforaminal disc but it is not routinely being used due to its some degree of invasiveness and lower specificity[14]. MRM was developed in late 1980's[12]. It has become one of popular auxiliary diagnostic methods used in brain or spinal lesion. MRM has several merits over conventional contrast media-using conventional myelography; non-invasiveness, no drug adverse reaction and so on[4]. Another advantage of this three dimensional MRM is that it provides precise thin sliced coronal views which are most close to operative fields in lumbar spine. So, surgeon can analyze the pathology of nerve roots more accurately with coronal views in addition to axial and sagittal images from routine MRI. Exact analysis of location, signal intensity and dimension of DRG is now possible by 3-dimensional MRM as signal-acquiring protocol and quality of image improve.

There are various mechanisms of DRG swelling. In chemical theory, exposed nucleus pulpous induces various substances like tumor necrosis factor, nitric oxide, interleukin-1β, prostaglandin E_2[7,9]. And these materials may cause cellular inflammatory reaction that results in edema. As for mechanical theory, root compression cause changes of endoneurial capillary pressure. Increased capillary vascular permeability causes breakdown of blood-nerve barrier. A leakage of fluid and macromolecules from these vessels out into the endoneurial space result in intraneural edema formation[10]. The length of exiting root also with the length of DRG itself is known to be the longest at L5-S1 than any other lumbar level[3,15]. DRG compression can be occurred by foraminal or extraforaminal disc, hypertrophied bony spur of vertebral body, thickened annulus, alar impingement, hypertrophic ligamentum or hypertrophied superior articular process and facet impingement on root at foramen[5,11]. The specificity of DRG swelling finding was 99.1% from this study and it means there is almost no chance of root swelling in asymptomatic people. Exceptionally, one patient who showed DRG swelling at normal side eventually developed mild L5 radicular pain after decompression of the other pathologic side and he underwent selective root block therapy later. Aota et al.[1] measured post-ganglionic L5 exiting root instead of DRG itself. They regarded spinal root is swollen if the size of exiting root is similar to that of the DRG. Their data showed no spinal root swelling in normal volunteers and the sensitivity and specificity of spinal nerve root swelling finding were 67% and 96%. These values were similar to our data of 60% and 99.1% respectively.

Abnormal running course means pathologic status of root direction such as horizontalization of DRG by upward migrated foraminal disc or sharp angulation by extraforaminal disc compression. Aota et al. reported about 22% of abnormal course of L5 nerve roots on MRM in asymptomatic normal volunteers. According to their data, incidence of RCA at symptomatic foraminal stenosis was 93% which is higher than our result, 65.5%. Lower incidence in this study is thought to be from slight different definition of RCA that root impingement by small and far-lateral disc herniation without change of running course was thought to be negative. Positive predictive value of running course abnormality from this study is 94.7% and it is much higher than that of Aota's result of 23.3%. But, their data was obtained from the unequal number of pathologic group and control group, 15 and 165. So, we re-calculated their data to make it comparable with our data. Their positive predictive value was 77% and it is slight lower than our data. When RCA was found in MRM, their real pathologic possibility was significant as statistically proven. When

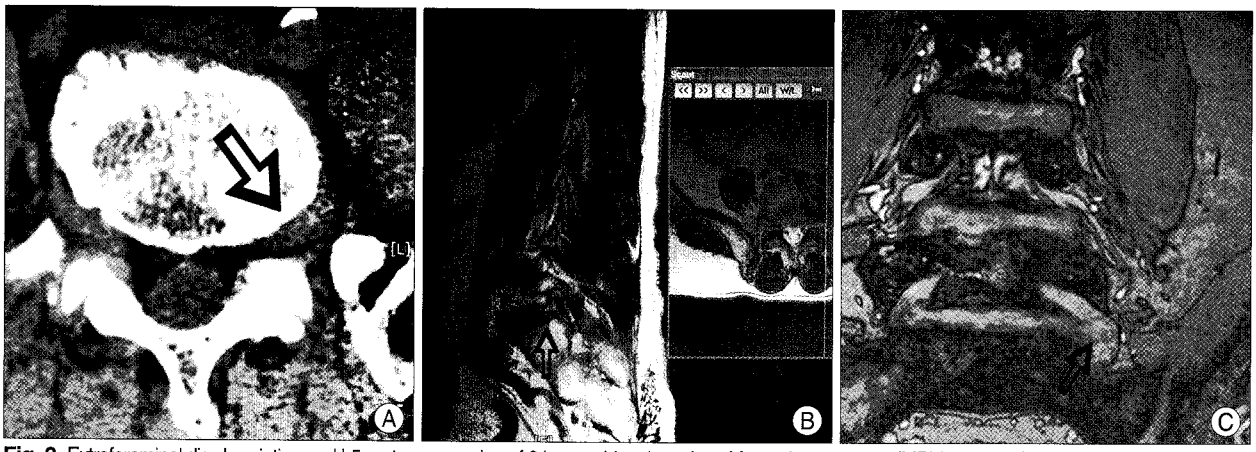

Fig. 2. Extraforaminal disc hemiation and L5 root compression of 64 year-old male patient. Magnetic resonance (MR) image and computed tomography (CT) scan failed to reveal any definite patholic lesion. The only clue is thin slice coronal source images of MR myelogram. A : CT scan shows slightly thickened left side L5 root shadow. B : Routinely ckecked MR image also does not prove definite Lt root compression focus. C : Coronal source image of MR myelography demonstrates definite extraforaminal disc hemation with L5 root impingement. Dorsal root ganglion at forament looked normal.

exiting root is compressed only by extraforaminal disc alone, most of cases showed no discernible morphologic change of DRG shape. Extraforaminal area is often missed by conventional CT or MRI so it was one of leading cause of postoperative failure of symptom relief[2,13,16]. Sometimes, extraforaminal L5 root impingement found in coronal source image might be the only radiologic clue when the other MRI or CT failed to prove definite root compression (Fig. 2).

In the diagnosis of L5-S1 foraminal or extraforaminal disc herniation, the sensitivity of routine MRI was known to be 93% and the sensitivity of DRG swelling and RCA from MRM was 93% and 67% according to Aota's study. Our MRM study results of sensitivity for each finding were 60% and 65.5% and MRM alone was not good enough to diagnose foraminal or exforaminal disc herniation. But, specificity of two findings from MRM was reported to be 72% and 96% and it was relatively higher than 52% of MRI[1]. The specificity of DRG swelling and RCA was 99.1% and 96.4% from this study and each value was higher than those of Aota's result. The existence of foraminal and extraforaminal disc herniation can be easily confirmed only by MRI alone due to its high sensitivity. But, when MRM is done additionally, the diagnostic value of specificity can be elevated from 52% to more than 90%. This means MRM is helpful in differentiating symptomatic lesion from asymptomatic foraminal or extraforaminal disc herniation. Coronal images of three dimensional MR myelogaphy are thought to be one of useful detecting methods of extraforaminal L5 root compression.

CONCLUSION

MRM gives sometimes useful information when conventional MRI and CT fail to prove definite lesion in patients who suffer definite L5 root radiculopathy. Two major findings, DRG swelling and RCA found in thin sliced coronal source images of MRM still useful in detecting foraminal and extraforaminal root compression and gives some hint about surgical focus where to decompress.

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