

Redundant Nerve Roots of the Cauda Equina : MR Findings¹

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Purpose : To evaluate MR findings of redundant nerve roots (RNR) of the cauda equina.

Materials and Methods : 17 patients with RNR were studied; eight were men and nine were women, and their ages ranged from 46 to 82 (mean 63) years. Diagnoses were established on the basis of T2-weighted sagittal and coronal MRI, which showed a tortuous or coiled configuration of the nerve roots of the cauda equina. MR findings were reviewed for location, magnitude, and signal intensity of redundant nerve roots, and the relationship between magnitude of redundancy and severity of lumbar spinal canal stenosis (LSCS) was evaluated.

Results : In all 17 patients, MR showed moderate or severe LSCS caused by herniation or bulging of an intervertebral disc, osteophyte from the vertebral body or facet joint, thickening of the ligamentum flavum, degenerative spondylolisthesis, or a combination of these. T2-weighted sagittal and coronal MR images well clearly showed the location of RNR of the cauda equina; in 16 patients (94%), these were seen above the level of constriction of the spinal canal, and in one case, they were observed below the level of constriction. T2-weighted axial images showed the thecal sac filled with numerous nerve roots. The magnitude of RNR was mild in six cases (35%), moderate in five cases (30%), and severe in six cases (35%). Compared with normal nerve roots, the RNR signal on T2-weighted images was iso-intense. All patients with severe redundancy showed severe LSCS, but not all cases with severe LSCS showed severe redundancy.

Conclusion : Redundant nerve roots of cauda equina were seen in relatively older patients with moderate or severe LSCS and T2-weighted MR images were accurate in identifying redundancy of nerve roots and evaluating their magnitude and location.

Index Words : Spinal canal, stenosis
Nerves, roots
Spinal cord, abnormalities

Redundant nerve roots (RNR) of the cauda equina are characterized by a tortuosity of elongated and enlarged nerve roots in the subarachnoid space of the lumbar spine. There are many published reviews deal-

ing with the myelographic findings of the RNR of the cauda equina and their pathogenesis (1–8), but no reports have detailed the findings of cross sectional study. The effectiveness of CT in viewing the subarachnoid nerve roots is limited, though high-field surface-coil MR techniques have adequately delineated the anatomic morphology of the cauda equina nerve bundles from surrounding CSF (9–10). In this article, we describe the MR appearance of RNR of the cauda equina, including their magnitude and location, and the relationship between magnitude of the redun-

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dancy and degree of lumbar spinal canal stenosis (LSCS).

Materials and Methods

Between June 1995 and November 1996, MR imaging was used to study 17 patients with RNR of the cauda equina. Eight were men and nine were women, and their ages ranged from 46 to 82 (mean 63) years. Reasons for MR study included back pain and signs of compressive radiculopathy, such as radiating pain, abnormal reflexes, loss of sensation, and loss of strength. In all patients, diagnoses were established on the basis of T2-weighted sagittal and coronal MR images, which showed a tortuous or coiled configuration of the nerve roots of the cauda equina.

All MR images were obtained with a GE Signa 1.5 Tesla scanner (General Electric, Milwaukee, WI) using a phase-array surface coil, and with settings as follows: field of view, 18–28cm; slice thickness, 4–5mm; interslice gap, 0–1mm; matrix, 256×256 or 512×256; and 2–4 excitations. Sequences included T2-weighted sagittal, coronal, and axial fast spin-echo imaging (TR/TE, 2500–4300/96–114) with an echo train length of 8–12, and T1-weighted sagittal and axial fast spin-echo imaging (TR/TE, 650/17) with an echo train length of 4.

MR findings were reviewed for location, magnitude, and signal intensity of RNR, and the relationship between magnitude of redundancy and severity of LSCS was evaluated. The magnitude of RNR was classified as

follows, according to the criteria of Tsuji and Tamaki (6): severe (severe redundant configurations with loop-shaped or serpentine-like streaking of a limited number of cauda equina roots); moderate (clear redundant configurations without loop-shaped shadows); and mild (mildly serpentine roots). LSCS was graded by measurement of the anteroposterior diameter of the thecal sac at mid-sagittal plane, and this was classified as mild (11–9mm), moderate (8–5mm), or severe (less than 5mm).

Results

MR findings are summarized in Table 1. In all 17 patients, MR revealed moderate or severe LSCS caused by herniation or bulging of an intervertebral disc, osteophyte from the vertebral body or facet joint, thickening of the ligamentum flavum, degenerative spondylolisthesis, or a combination of these. On T2-weighted images, nerve root morphology and surrounding CSF were well delineated, and in each case, the location and magnitude of redundancy varied. In all patients except one, T2-weighted sagittal and coronal MR images revealed RNR of the cauda equina above the level of constriction of the spinal canal (Figs. 1A, B; Figs. 2A, B; Fig. 3); in one case, these were seen below the level of LSCS (Fig. 4). T2-weighted axial images above the level of the constricted spinal canal showed the thecal sac filled with numerous nerve roots (Fig. 1C). Compared with normal roots, the RNR signal on T2-weighted images was iso-intense.

Table 1. Magnitude and Location of RNR, and Severity, Level, and Main Causes of LSCS.

Patient/Age(yr)/Sex	Magnitude of RNR	Location of RNR	Severity of LSCS (Level)	Main causes LSCS
1/57/M	Severe	Above	Severe (L1-2)	HNP with osteophytes
2/54/F	Severe	Above	Severe (L3-4, L4-5)	HNP and facet changes*
3/69/F	Severe	Above	Severe (L2-3)	HNP with osteophytes
4/56/F	Severe	Above	Severe (L3-4, L4-5)	Degenerative spondylolisthesis
5/61/F	Severe	Above	Severe (L3-4, L4-5)	HNP and facet changes
6/72/F	Severe	Above	Severe (L3-4, L4-5)	HNP with osteophytes
7/60/M	Moderate	Above	Severe (L3-4)	HNP with osteophytes
8/82/M	Moderate	Above	Severe (L3-4, L4-5)	HNP with osteophytes
9/55/M	Moderate	Above	Moderate (L2-3)	HNP
11/70/F	Moderate	Above	Moderate (L3-4)	Old compression fracture
14/57/F	Moderate	Below	Moderate (L4-5)	HNP with osteophytes
10/46/F	Mild	Above	Severe (L4-5)	HNP with osteophytes
12/66/M	Mild	Above	Severe (L4-5, L5-S1)	HNP with osteophytes
13/62/M	Mild	Above	Severe (L2-3)	HNP
15/60/M	Mild	Above	Severe (L2-3)	HNP
16/75/F	Mild	Above	Moderate (L4-5)	HNP
17/67/M	Mild	Above	Moderate (L3-4)	HNP with osteophytes

* facet hypertrophy, facet osteophytes, and ligamentum flavum thickening

In all patients, MR revealed moderate or severe LSCS, and six patients with severe RNR all showed severe LSCS (Table 2). Some positive relationship was suggested between magnitude of the redundancy and the degree of LSCS, but the latter could not be used as a basis for determining the former.

Discussion

RNR of the cauda equina were first described by Verbiest in 1954 and named by Cressman and Paul in 1968 (1). Since then, the condition has been assumed to

be a rare congenital anomaly, but accumulating reports have revealed its frequent association with a narrow lumbar spinal canal, either developmental or acquired (4, 5). Tsuji and Tamaki pointed out a possible relationship between RNR and LSCS (6), and more recently, Suzuki et al. described a close causal relationship between RNR and constriction of the spinal canal, and stated that the pathogenesis of the RNR was a squeezing force acting on the nerve roots at the area of spinal canal constriction (8). At present, RNR of the cauda equina are considered to be rather common in patients with LSCS. Undulant or finely-wrinkled appearance of

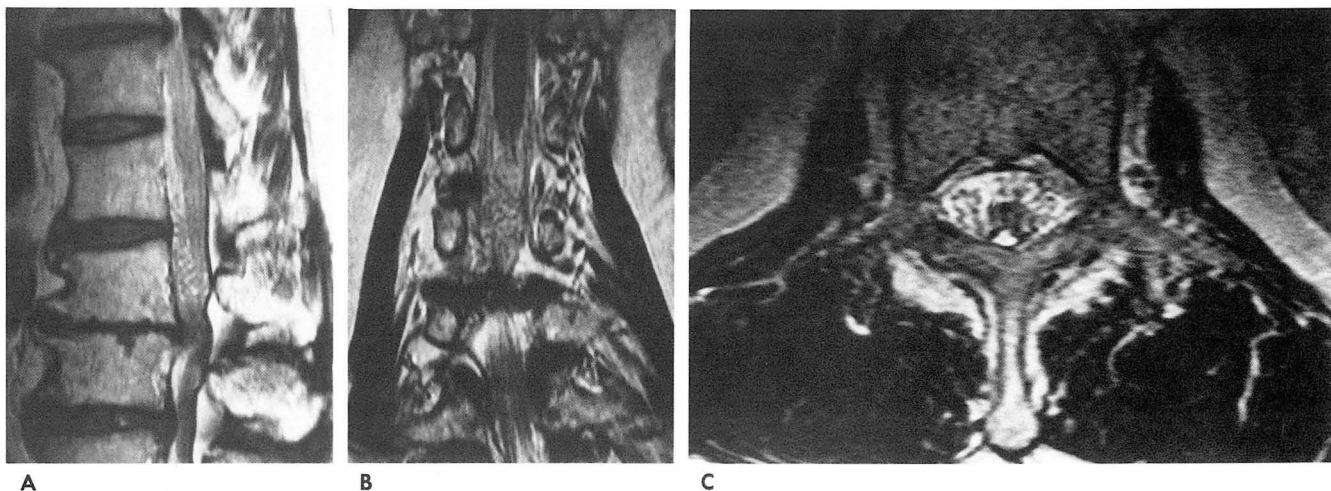


Fig. 1. A. T2-weighted sagittal image shows severe spinal stenosis at L2-3, secondary to posterior osteophytes and disc bulging. Severe RNR of the cauda equina are seen above the level of stenosis.
B. T2-weighted coronal image also shows tortuous nerve roots.
C. T2-weighted axial image at L2 level. The thecal sac is filled with numerous nerve roots.

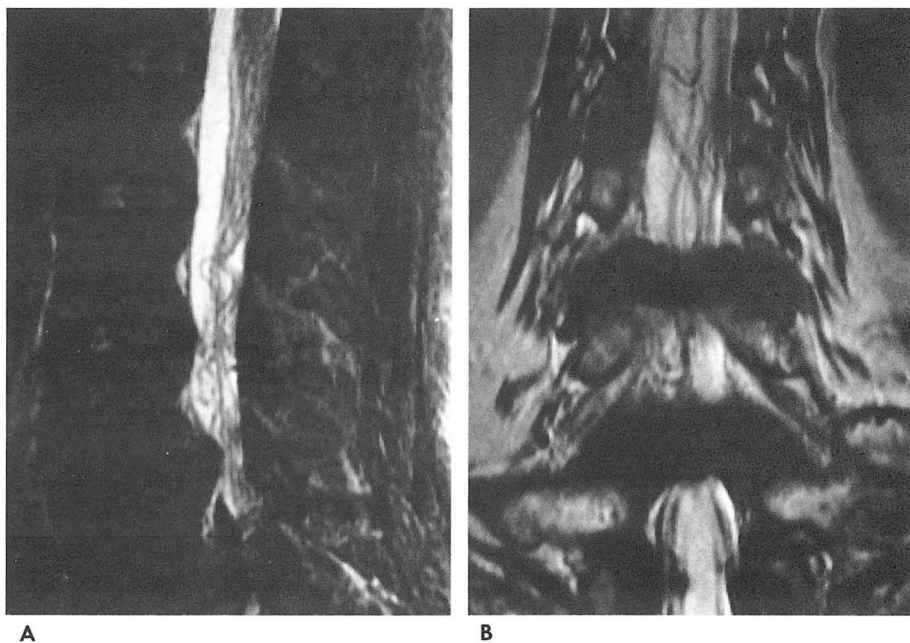


Fig. 2. A. T2-weighted sagittal image with fat suppression reveals severe degenerative spinal stenosis at L3-4 and L4-5. Severe RNR are present above the level of stenosis.
B. T2-weighted coronal image. Serpentine course of the nerve root is more adequately defined.

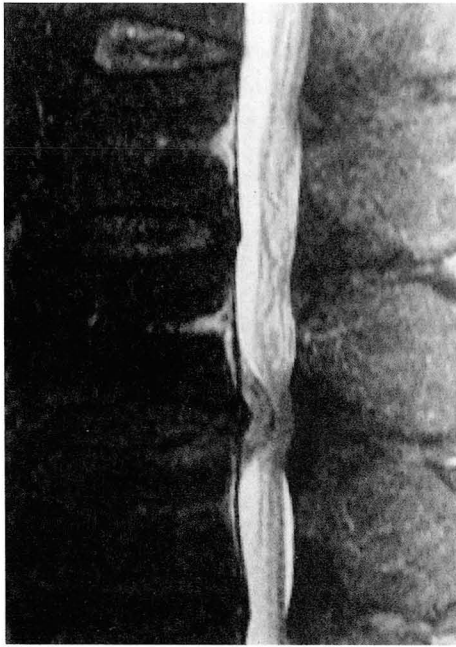


Fig. 3. T2-weighted sagittal image shows mild redundancy of nerve roots above the level of severe constriction of spinal canal at L2-3 caused by herniated nucleus pulposus.

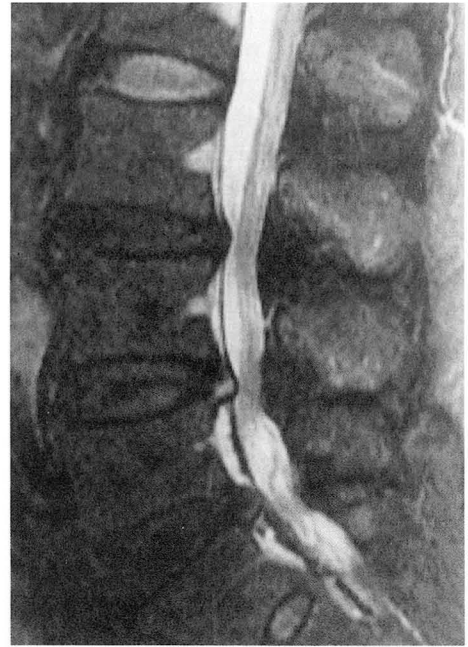


Fig. 4. T2-weighted sagittal image. Moderate redundancy of nerve roots is defined caudal to the moderate constriction of spinal canal at L4-5.

Table 2. Relationship between Magnitude of RNR and Degree of LSCS

Magnitude of RNR	Degree of LSCS		
	Severe	Moderate	Mild
Severe	6	0	0
Moderate	2	3	0
Mild	4	2	0

nerve roots of the cauda equina are reported to have been found in approximately 45% of the fixed cadavers (6).

On myelography, RNR of the cauda equina show serpentine filling defects, but a similar myelographic appearance may also be caused by the engorgement of subarachnoid veins, arteriovenous malformation, vascular tumor, and hypertrophic interstitial polyneuritis. Cross-sectional studies, including those involving CT and MR, have not been reported, however. The effectiveness of MRI in visualization of the anatomic morphology of nerve bundles of the cauda equina has been well documented (9–10). T2-weighted spin-echo sequencing provides detailed definition of the nerve roots, distinguishing them from surrounding CSF. To assess the pathology of the nerve roots of the cauda equina, MRI is preferred to myelography and CT as a diagnostic tool.

The nerve roots of the cauda equina descend along-

side the cornus medullaris and are predominantly situated in the posterior part of the thecal sac. On T2-weighted sagittal and coronal images, they appear as uniform low-intensity linear structures, and the individual nerve roots become visible as they descend anteriorly and laterally toward their exits. On T2-weighted axial images, nerve roots are seen individually or in clusters as low-intensity dot-like structures which are predominantly located in the posterior aspect of the dural sac.

In our study, T2-weighted sagittal and coronal MR images revealed tortuous, serpentine, or loop-shaped nerve roots of the cauda equina; these showed low signal intensity, as did normal nerve roots. These findings could be easily differentiated from vascular malformation, which showed foci of high-velocity signal loss or high signal intensity within the enlarged vessels. On T2-weighted axial images, numerous nerve roots filled up the thecal sac and this finding suggested RNR. Nerve root redundancy usually occurs cephalad to the stenotic segment, but RNR caudal to the stenotic segment have been reported (6, 11). In our 17 cases, one patient showed RNR of the cauda equina below the level of LSCS.

Patients with RNR have a non-specific clinical picture of long-standing and progressively disabling radiculopathy or neurogenic intermittent claudication. The clinical significance of RNR seen in degenerative spinal stenosis is not fully understood, but

in patients with RNR, the period from the onset of symptoms is longer, and more severe signs and symptoms are seen than in patients who do not have RNR (7). It has been reported that no clear relationship existed between magnitude of redundancy and severity of spinal canal stenosis, and that the chronicity of LSCS could affect the magnitude of RNR (7). In our study, all patients with severe redundancy showed severe LSCS, but not all cases with severe LSCS showed severe redundancy. All patients were, in addition, relatively old.

A favorable outcome could be achieved by decompressive laminectomy and intradural exploration for additional decompression, but recovery after operation has been reported to be less in patients with RNR than in those who are not suffering from this condition (7). Surgical investigation has revealed hypertrophic change of the individual nerve roots, a sort of friction neuritis, and arachnoidal adhesion (6); in a pathologic study of RNR, various degrees of irreversible change, demyelination, and axonal loss also have been reported. (8). Complete relief of symptoms is rare. It has been reported that nerve root redundancy was inadequately relieved after lumbar decompressive laminectomy without dural incision (5), so postoperative study is needed.

In conclusion, RNR of the cauda equina were seen in relatively older patients with moderate or severe LSCS. Redundancy usually occurred above the level of constriction of the spinal canal and signal intensity was the same as that shown by normal nerve roots; T2-

weighted sagittal and coronal MR images were accurate in identifying nerve redundancy and evaluating its magnitude.

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과신전 마미충 신경근: 자기공명영상 소견¹

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목 적 : 과신전 마미충 신경근의 자기공명영상 소견을 알아보고자 하였다.

대상 및 방법 : 요추 자기공명영상을 시행한 환자 중 꾸불꾸불하거나 나선 모양의 마미충 신경근이 관찰되어 과신전 마미충 신경근으로 진단할 수 있었던 17명(남자 8, 여자 9, 평균연령 63)을 대상으로 횡단, 시상 및 관상영상에서의 과신전된 신경근의 분포 및 과신전 정도, 신경근의 신호강도, 그리고 요추척수강협착증과의 관계를 분석하였다.

결 과 : 17예 모두에서 추간관 탈출증, 추체 및 척수관절돌기의 비후, 황색인대의 비후, 또는 퇴행성 척추전방 전위증 등에 의한 중등도 이상의 요추척수강협착증의 소견을 보였다. T2 강조 시상 및 관상영상에서 과신전된 마미충 신경근을 16예에서는 협착된 척수강 위쪽에서, 나머지 1예에서는 협착된 척수강 아래쪽에서 관찰할 수 있었고, T2 강조 횡단영상에서는 정상보다 많은 신경근에 의하여 척수강이 채워진 양상을 보였다. 신경근의 과신전 정도는 경도 6예(35%), 중등도 5예(30%), 그리고 고도 6예(35%) 이었다. T2 강조영상에서 과신전된 신경근은 정상 신경근과 동일한 신호강도를 보였다. 고도의 과신전 신경근 소견을 보인 6예 모두에서 고도의 요추척수강협착증을 보였지만, 고도의 요추척수강협착증을 보인 환자가 모두 고도의 과신전 신경근 소견을 보이지는 않았다.

결 론 : 과신전 마미충 신경근은 비교적 나이가 많은 환자에서 중등도 이상의 요추척수강협착증과 관련되어 나타나며, T2 강조 자기공명영상이 이의 진단, 과신전 정도 및 분포 등의 관찰에 유용한 것으로 생각된다.