# Role of Magnetic Resonance Imagining in the Surgical Management of Herniated Lumbar Disc in Cases with Nerve Root Anomalies

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## ABSTRACT

***Objective*** *The objective was to determine the importance of the "sagittal shoulder sign" on magnetic resonance (MR) images for the diagnosis of conjoined Lumbosacral nerve roots (CLNR) that are compromised by herniated discs.* ***Materials and Methods****: Magnetic resonance images of 11 patients (6 men and 5 women; age range, 25-71 years; average age, 48.7 years) with surgically proven CLNR, which was compromised by herniated discs, were retrospectively evaluated by two radiologists. MR images were evaluated for the presence or absence of the sagittal shoulder sign – a vertical structure connecting two nerve roots and overlying disc on the sagittal MR images. The radiologists noted the type of accompanying disc herniation and bony spinal canal changes, as well as other characteristic MR features of CLNR, the common passage of two consecutive nerve roots through the neural foramen on axial MR images.* ***Results:*** *The sagittal shoulder sign was identified with a mean frequency of 90.9% by the two observers (in 10 of 11 patients, by observers 1 and 2, respectively). Good interobserver agreement for the sagittal shoulder sign was present ($k = 0.621$, $p < 0.05$).* ***Conclusion:*** *Observation of the sagittal shoulder sign may prove helpful for diagnosing CLNR in patients with disc herniation. In particular, this sign appears to be useful when there is no evidence of CLNR on axial MR images.*

***Keywords*** *Spinal nerve roots – Lumbosacral region – Abnormalities – Intervertebral dik displacement – Magnetic resonance imaging*

## INTRODUCTION

A conjoined Lumbosacral nerve root (CLNR) is composed of two adjacent nerve roots, which share a common dural envelope at some time during their coursing from the thecal sac. It is believed that the development of an anomalous nerve root is secondary to aberrant migration of the involved roots during embryologic development[(1)].

Conjoined Lumbosacral nerve root is frequently underrecognized on magnetic resonance imaging (MRI) and may account for a percentage of failed spinal surgical procedures. Unsuspected CLR can provoke lesions and trauma of the nerve roots during operative treatment. Preoperative diagnosis of the nerve root anomalies is essential, not only for the explanation of atypical clinical findings[(2,3)], but also in the selection of both safe and effective surgical approaches to the lumbar spine[(4, 8)].

Most cases of CLNR were incidental findings during operations for herniated lumbar intervertebral discs. In order to make a preoperative diagnosis, some authors proposed that a negative Leasigue's sign[(9)], or a biradicular syndrome[(10)], can be clinically suggestive for a nerve root anomaly. Since the introduction of myelography it has become possible for the first time to diagnose the anomaly preoperatively. CT imaging of nerve root anomalies often causes misinterpretation of anatomical variations such as disc herniations[(11,12)]. The constellation of CLNR and herniated disc or the

associated presence of spinal stenosis often leads to difficulties in the preoperative diagnosis of CLNR on MRI, although MRI is the gold standard for differentiation the presence of CLNR from other space-occupying processes.

We recently noticed a useful MR feature predictive of CLNR that are compromised by disc herniation, a feature that we termed the "sagittal shoulder sign". The purpose of this study was to increase the radiologist awareness of the potential presence of CLNR that are accompanied by disc herniation, and to determine the importance of the sagittal shoulder sign, which is predictive of CLNR on preoperative MR investigations and will help in selection of both safe and effective lumbar spine surgery.

## MATERIALS & METHODS

### Patient population

Surgical records of 300 patients who underwent lumbar spinal operation for a symptomatic disc herniation or degenerative spinal stenosis between May 2003 and November 2006 at Ain Shams university hospitals and Ain Shams Specialized hospital were searched for cases of CLNR. During this period, the presence or absence of CLNR was specifically assessed by one Neurosurgeon. In 11 patients, CLNR was identified in conjunction with disc herniation during the operation. The average patient age was 48.7 years (range 25-71 years), and there were 5 women and 6 men.

### MRI and image evaluation

All patients in the study underwent MR imaging with 1.5-T unit (Signa, L.X, GE, USA & Philips Intra) before operation. The imaging protocol consisted of sagittal and axial T1-weighted images (TR/TE, 550-750/12-30) and sagittal and axial fast spin-echo or turbo spin-echo T2-weighted images (TR/TE, 3.500-3.600/112-120). Typical MR parameters were as follows: field of view, 15 – 20 cm for axial plane and 30 – 35 cm for sagittal plane; two to four excitations; matrix size, 512 – 256 x 256 – 192; the slice thickness, 3 – 4 mm; interslice spacing, 0.4 – 1 mm; and echo train length, 3 – 15.

Magnetic resonance images were interpreted independently by two radiologists; both observers were blinded to the lumbar level of the surgically confirmed CLNR. The sagittal shoulder sign was defined as a vertical structure connecting two consecutive nerve roots and the overlying herniated disc on the parasagittal MR images, representing a combination of protruded or extruded disc and CLNR (Fig. 1) Both sagittal T1-weighted and T2-weighted MR images were carefully assessed to trace the sagittal shoulder sign and this sign was considered present when it was possible to differentiate a herniated disc from a vertical structure. Additionally, the presence of the common passage of two consecutive nerve roots through the neural foramen on axial MR images was also evaluated during the same reading session. This feature was considered present when there was a broader dural sheath where the roots converged on the dura or the presence of confluent rootlets taking off at the level midway between the mirror-image roots. This feature, which was named an axial common passage sign (Fig. 2) in this study, has been considered to be a specific MR sign for the diagnosis of CLNR[13]. Therefore, it was used in comparison or in combination to verify the significance of the sagittal shoulder sign in diagnosing CLNR in patients with disc herniation. The location of disc fragments coinciding with CLNR was noted and the presence or absence of

bony anomaly associated with CLNR was assessed.

**Record review**

The patient's medical records and surgical reports were reviewed to determine each patient's clinical presentation. All patients underwent discectomy and laminectomy with wide exposure, and 5 of them underwent posterior lumbar interbody fusion as well as discectomy and laminectomy. Percutaneous endoscopic lumbar discectomy or microdiscectomy was not performed in any of the patients. The surgeon confirmed the presence of CLNR when he identified that the two nerve roots arose from a common dural sheath.

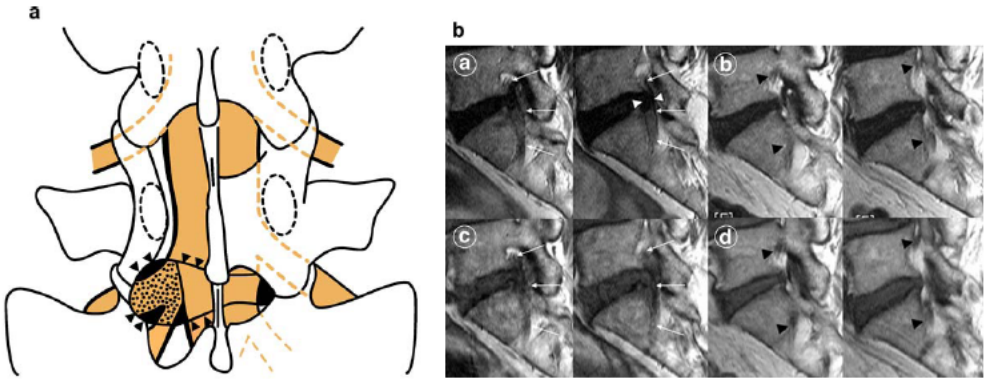


***Fig. 1: (a) Drawing shows conjoined L5S1 rootlets (dotted area) compromised by a herniated disc fragment (arrow heads). Note asymmetry of the radicular sleeves and the midway position of the conjoined trunk. (b) The sagittal shoulder sing was defined as vertical space_occupying structures (arrows) connecteing two adjacent nerve roots and the overlying herniated disc (white arrow heads) on sequential sagittal T2 and T1 weighted images (a, c) this sign was easily understandable compared with the contralateral sagittal images (b, d), which showed separate nerve roots (black arrow heads) in the normal position.***

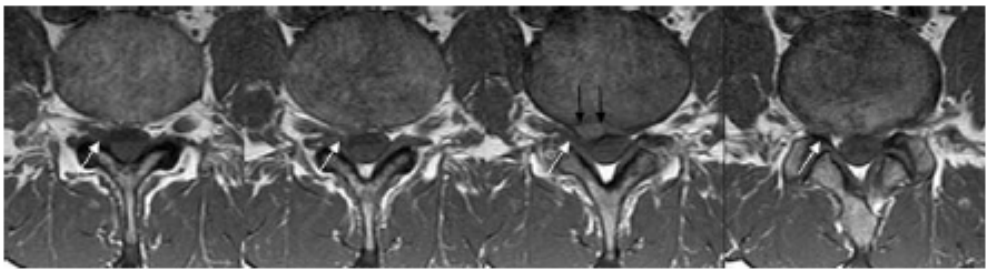

***Fig. 2: A 40 years old woman with axial common passage sign. Consecutive T1 weighted axial images show the presence of the common passage of two consecutive nerve roots through the neural foramen. Which is compromised by a herniated disc fragment (black arrow) taking off asymmetrically between the mirror image roots.***

**Statistical analysis**

To obtain an objective indication of the frequency of occurrence of the sagittal shoulde sign and the axial common passage sign, each of the two observers independently recorded the presence of absence of these signs on MR images. The resultant data were analyzed for interobserver agreement, by using statistical software and in consultation with a statistician. The level of agreement was defined as follows: kappa values less than 0 were considered to indicate no agreement; 0.00 – 0.40 poor agreement; 0.41 – 0.60 fair agreement; 0.61 – 0.80 good agreement; and 0.81 - 1 .00 excellent agreement.

## RESULTS

Our study comprised 11 patients with a combination of herniated disc material and CLNR, representing 3.6% of a total of patients who underwent spinal operations for symptomatic disc herniation of spondylotic spinal stenosis in the Department of Neurosurgery, Ain Shams University hospitals and Ain Shams Specialized hospital. The principal clinical findings, together with the MRI findings and surgical reports, are summarized in Table 1.

In all 11 patients, the presence of CLNR was verified by the two observers who assessed the MR images. On the level and location of CLNR, agreement was reached between the two observers. In 5 patients, the L5 and S1 nerve root were involved; 5 patients had conjoined L4 and L5 nerve roots; and 1 patient had conjoined L3 and L4 nerve roots; and 1 patient had conjoined L3 and L4 nerve roots. There was no cases of bilateral anomalies in our study. All 11 patients presented wit radicular pain on the same sides where CLNR was identified.

At MRI, the location of the herniated disc fragments at the lumbar segment with CLNR was diagnosed as follows: right/left central (4 patients), right/left foraminal (4 patients), central (2 patients), right/left subarticular (1 patient). In 3 patients, the following bony anomalies were found in conjunction with CLNR: dysplastic lamina, hypoplastic pedicle, and enlargement of the lateral recess respectively.

The sagittal shoulder sign was observed in 10 patients (90.9 %) by both observers. The axial common passage sign was observed in 7 patients (63.6 %) by observer 1 and in 6 patients (54.5 %) by observer 2. The interobserver agreement regarding the presence of the sagittal shoulder sign was good as indicated by the k and p values obtained with statistical analysis (Table 2) Regarding the presence of the axial common passage sign, excellent interobserver agreement was present. Both these two signs ere simultaneously observed in 6 patients by observer 1 and in 5 patients by observer 2 (Fig. 3). In the 4 patients who had a frank central spinal stenosis in conjunction with disc herniation and CLNR, only the sagittal shoulder sign was observed by both observers (Fig. 4).

**Table 1.** Clinical and operative and MRI findings in 11 patients with conjoined lumbosacral nerve root *(CLNR)*

| ***Patient no/ sex*** | ***Symptoms*** | ***Duration*** | ***Surgical reports*** | ***MR findings*** |
|---|---|---|---|---|
| 1/female | LS, LBP | 1 month | CLNR L4-L5 left; inflamed CLNR splayed over a herniated disc fragment | Left central disc herniation; central spinal stenosis and left neural foraminal stenosis; dysmorphic lamina on the left side |
| 2/female | LS, LBP | 3 years | CLNR L4-L5 left; inflamed CLNR compressed by a herniated disc fragment | Left foraminal disc herniation; hypoplasia of the pedicle |
| 3/female | LS, LBP | 5 months | CLNR L4-L5 left; inflamed CLNR compressed by a large herniated disc fragment | Left central disc herniation; severe dural sac compression (central spinal stenosis) due to disc herniation; no bony anomaly |
| 4/male | LS, LBP | 4 months | CLNR L4-L5 left; inflamed CLNR splayed over a hemiated disc fragment | Left foraminal disc hemiation; central spinal steno! no bony anomaly |
| 5/male | RS, LBP | 6 months | CLNR L5-S1 right; CLNR contact with a hemiated disc fragment | Right central disc herniation; no bony anomaly |
| 6/female | RS, LBP | 3 months | CLNR L5-SI right; CLNR compressed by a Herniated disc fragment | Right foraminal disc herniation; widening of the lateral recess on the right side |
| 7/female | RS, LBP | 2 weeks | CLNR L3-L4 right; inflamed CLNR compressed by a large herniated disc fragment | Right central disc herniation; severe dural sac compression (central spinal stenosis) due to disc herniation;no bony anomaly |
| 8/male | RS | 3 weeks | CLNR L5-S1 right; inflamed CLNR splayed over a herniated disc fragment | Right foraminal disc herniation; isthmic spondylolisthesis at upper segment (L4-L5); no bony anomaly |
| 9/male | RS. LBP | 1 year | CLNR L5-S1 right; CLNR contact with a herniated disc fragment | Central disc herniation; no bony anomaly |
| 10/male | RS. LBP | 6 months | CLNR L5-SI right; CLNR compressed by a herniated disc fragment | Central disc herniation; no bony anomaly |
| 11/male | RS. LBP | 3 months | CLNR L4-L5 right; inflamed CLNR compressed by a herniated disc fragment | Right subarticular disc herniation; no bony anomaly |

*LBP* low back pain, *LS* left sciatica, *RS* right sciatica

**Table 2:** Inter-observer agreement regarding the presence of the sagittal shoulder sign and the axial common passage sign.

| ***MR signs predictive of CLNR*** | ***K statistic*** | ***p value*** |
|---|---|---|
| Sagittal shoulder sign | 0.621 | <0.05 |
| Axial common passage sign | 0.814 | <0.01 |

p value of <0.05 was considered to indicate statistical significance.

## DISCUSSION

Various types of anomalies of the Lumbosacral nerve roots have been documented in the available literature. In 1962, Cannon et al.[1] proposed the first classification of nerve root anomalies. In type I (conjoined type), two roots share a common sleeve that originates from a dura matter. In type II (anastomotic type), a normal root bifurcates abnormally after it leaves the dura and branches out to the next caudal nerve. In type III (transverse type), the nerve root leaves the dural sac, almost at a right angle. Other classifications have been proposed by Postacchini et al.[14], by Neidre and McNab[15], by Kadish and Simmons[16] and by Kikuchi et al.[3].

The statistical prevalence of CLNR varies from an incidence of 14 % to low single numbers. The reason we believe, is that the anatomic study that reported 14 % includes a wide variety of nerve root anomalies, whereas the study by Epstein et al. refers primarily to anomaly type I[4,16]. Myelography with water-soluble contrast media detected CLNR in 4 % of patients examined[17]. In a series of 8.000 CT scans, a 2 % incidence was observed[8]. In the series of Haijiao et al.[18] 2 cases of CLNR were found in the review of 376 MR exanimations and Scuderi et al.[13] Reported a 5% incidence in the evaluation of microsurgical lumbar discectomies in 80 patients. Our study compromised 11 patients with CLNR, representing 3.6% of a total 300 patients who underwent spinal operations for a symptomatic disc herniation or spinal stenosis. In any case it is probable that CLNR are more common that the radiologic reports seem to indicate.

From the clinical point of view, CLNR usually do not initially produce any symptoms. It is only when further degeneration of discs and/or vertebral joint occurs (often accompanied by stenosing of the spinal canal and of the root canal entrance) that clinically relevant root compressions may be observed. The presence of additional abnormalities or degenerative changes, such as disc herniation or lateral recess stenosis, supports the development of low back pain[7,19,20]. Ethelberg and Riishede[2] reported that since the anomalous nerve roots occupied the entire limited intraspinal space, further diminution of the available space by as light change in the intervertebral disc resulted in compression. Since a disc bulge or herniation is quite common, especially in the lower lumbar segments where CLNR most commonly occurs, CLNR may be misdiagnosed as a bulging or herniated disc or nerve root swelling on preoperative MRI. Therefore, the incidence of CLNR may be higher than previously suspected and it is quite possible that many patients with persistent raduculopathy in the presence of the appearing disc bulges or herniation or spinal stenosis may, in fact, be manifesting symptoms of a stretch injury to a tethered CLNR.

Myelography has been stated to provide excellent visualization of anomalous nerve roots by the dye's ability to fill the entire nerve root sleeve[17]. However, if only myelography is performed, it cannot reliably ascertain the coexistence of lateral recess stenosis or other associated factors causing neural entrapment besides the conjoined nerve[21]. In CT scans the presence of CLNR may be suspected if isodense or slightly hyperdense tissue replaces the anterolateral area of the epidural space. The estimation of attenuation values is helpful, as it allows the differentiation of denser herniated discs from dural sac structures[22]. Sometimes two

separate, conjoined round structures, which can be followed in the next slices through the neural foramen, can be observed. These findings could be applicable to the axial common passage sign used in our study.

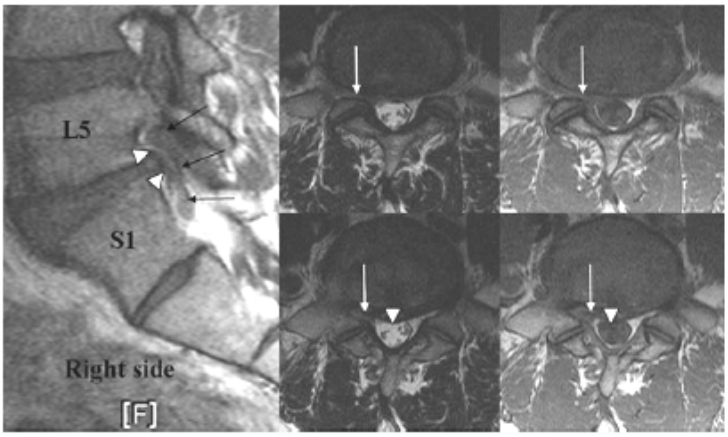


***Fig. 3: 49 years old man with right sciatica and low back pain. In this case, both the sagittal shoulder sign (black arrows and the axial common passage sign (white arrows) were considered present by both observers. CLNR contact with a centrally herniated disc fragment (arrow heads) was identified intraoperatively.***

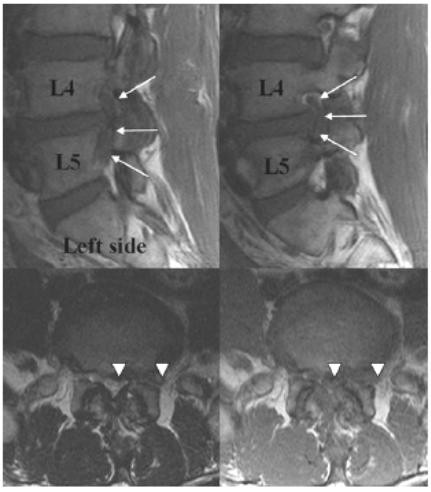


***Fig. 4: 52 years old man with left sciatica and low back pain. <u>Top</u>: consecutive sagittal T1 weighted images show the presence of the sagittal shoulder sign (arrow heads) imaged by conjoined left L4 and L% nerve roots. <u>Bottom</u>: Axial T2 and T1 weighted images show central spinal stenosis in conjunction with left foraminal disc herniation (arrow heads). On axial images, its very difficult to differentiate herniated disc fragments from CLNR.***

A secondary sign of CLNR is an abnormal configuration of the dural sac and/or impression of associated bony structures[23]. However, the combination of CLNR and herniated disc or the associated presence of spinal stenosis leads to difficulties in differential diagnosis between herniated disc formations and CLNR CT imaging [19,21].

Magnetic resonance imaging is the gold standard for differentiating the presence of CLNR form other space-occupying processes such as disc herniation. According to the previous report by Scuderi et al.[13], several

characteristic features of CLNR are noted on MRI. The signal intensity of a nerve root anomaly is almost identical to that of the thecal sac on a T2-weighted image. Also, the location of the root anomaly is often above the intervertebral disc space at the level of the pedicle, while herniated disc fragments are usually seen at the level of the disc space. Often, an asymmetry or pouching out of the subarachnoid space in the axial view suggests the presence of CLNR. Although such findings have been thought to be helpful in predicting the presence of CLNR, they may not be conclusive enough according to circumstances. In our experience, it is very difficult to make the diagnosis of CLNR compromised by disc herniation or severe spinal stenosis on the basis of axial MR images.

Gomez et al.[24] emphasize that both the coronal T2-weighted MR image and the classic myelography for the lumbar spine demonstrate the nerve anomalies noninvasively and with equal sensitivity. Recently, the use of the classic myelography or CT myelography has been replaced with the routine use of MRI. Coronal MRI allows the viewer to follow the take-off of several nerve roots in the same plane of imaging and therefore is the optimal imaging plane to evaluate other Lumbosacral nerve root anomalies as well as CLNR[25]. However, we believe that MRI scanning traditionally utilizes two planes of imaging, namely sagittal and axial, to evaluate the degenerative lumbar spine in most institutions. In these circumstances, the authors paid attention to the specific MR features of CLNR seen on the routine sagittal and axial images. In this study, it was highly suggestive of the presence of CLNR that anomalous nerve roots overlie the herniated fragment or bulging disc on sagittal MR images. These appearances are characteristic enough to allow a specific diagnosis to be made. In our series, the sagittal shoulder sign was demonstrated in most of the patients with CLR.

Unfortunately, the most common environment in which CLNR are diagnosed is the operating room, which dramatically increases the potential for an iatrogenic complication. In particular, these potential failures may increase with the rising popularity of minimally invasive therapies due to the sacrifice of enhanced visualization encountered with maximal incision surgery. The surgical success of patients undergoing standard hemilaminectomy and discectomy in the setting of a conjoined nerve root anomaly is often less than satisfactory[26]. It is technically more difficult to remove a herniated disc in the presence of a CLNR. In patients with this anomaly, adequate exposure of the roots involved to avoid persistent compression and to reduce any traction may be necessary, keeping in mind that a hemilaminectomy with sufficient exposure of the intervertebral foramen or of the lateral recess should be performed to avoid the alterations of stability and to ensure correct mobility of the Lumbosacral spine [25,27].

A major limitation of our study is that it did not determine the sensitivity and specificity of two MR signs for preoperative diagnosis of CLNR. Because there was no control group of patients who underwent lumbar spinal operation for a significant disc herniation or spinal stenosis without CLNR, the presence and frequency of the sagittal shoulder sign and the axial common passage sign in patients without CLNR were not determined. In addition, myelography, CT myelography, or coronal MRI was not performed in all patients. Therefore, the detailed classification of CLNR was not determined in this study, thus

not allowing assessment of the association of MR signs and the accurate type of CLNR.

**In conclusion,** the current study showed that a fairly accurate diagnosis can be derived from MRI in the axial and sagittal planes in the preoperative evaluation of CLNR. In particular, the sagittal shoulder sign on sagittal MR images can be helpful in the detection of CLNR compromised by disc herniation.

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