Multiplanar Reconstruction Computed Tomography of Lumbar Spinal Stenosis in Correlation with Surgical Findings: Initial Experience

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Abstract : **Lumbar spinal stenosis is a debilitating illness affecting middle-aged and elderly people. There are several imaging modalities available for use in affirming the diagnosis. The CT provides excellent osseous detail of osteophyte, fracture and location of bony abnormality and extension to adjacent soft tissue. New spiral CT technology allows multiplanar images to be obtained quickly and easily. Among these, multiplanar reconstruction computed tomography (MPR-CT) is the specific means to assess narrowed lumbar spinal canal. This present work was done in order to evaluate the reliability of MPR-CT in diagnosing lumbar spinal stenosis by correlation with operative findings.**

From July to December 2002, MPR-CT was done on 10 patients and evaluated by a well-known radiologist. Seven patients were approached surgically and the remaining three treated medically. Subsequently, the following variables were analyzed: central canal stenosis, lateral canal stenosis, foraminal stenosis, disc herniation, nerve root compression, ligamentum flavum hypertrophy and spondylolisthesis.

The results of MPR-CT were in good correlation with findings from surgical exploration; the positive predictive values of central canal stenosis, lateral canal stenosis and foraminal stenosis were 77.7%, 75% and 50% respectively which were higher than those for disc herniation or nerve root compression. Typical claudication was found in 10% of the cases and the most common affected level was L4-L5.

Therefore, MPR-CT which composed of axial, coronal and sagittal views was shown to be an applicable imaging modality because of its reliability.

เรื่องย่อ : MPR-CT ในการวินิจฉัยภาวะตีบแคบของช่องไขสันหลังระดับเอวโดยเปรียบเทียบกับผลการผ่าตัด

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สารศิริราช 2546; 55: 478-490.

ภาวะตีบแคบของช่องไขสันหลังระดับเอว (lumbar spinal stenosis) เป็นภาวะที่พบบ่อยในกลุ่มคนอายุมากและวัยกลางคน ซึ่งสามารถให้การวินิจฉัยโดยภาพทางรังสีวิทยาได้หลายอย่าง Multiplanar reconstruction computed tomography (MPR-CT) เป็นวิธีการใหม่ในการวินิจฉัยภาวะตีบแคบของช่องไขสันหลังระดับเอว งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาประโยชน์ของ MPR-CT ในการวินิจฉัยภาวะตีบแคบของช่องไขสันหลังระดับเอวโดยเปรียบเทียบกับผลการผ่าตัด

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ได้ทำการศึกษาตั้งแต่เดือน กรกฎาคม ถึง ธันวาคม 2545 มีผู้ป่วยที่ได้รับการวินิจฉัยภาวะตีบแคบของช่องไขสันหลังระดับเอว จำนวน 10 ราย โดยใช้ MPR-CT ในจำนวนนี้มีผู้ป่วย 7 รายที่ได้รับการผ่าตัด ผู้ป่วยอีก 3 รายได้รับการรักษาโดยยา (conservative treatment) การวินิจฉัยภาวะนี้ให้ความสนใจในหัวข้อต่อไปนี้ central canal stenosis, lateral canal stenosis, foraminal stenosis, disc herniation, nerve root compression, ligamentum flavum hypertrophy และ spondylolisthesis

ผลการศึกษาโดยเปรียบเทียบภาพทางรังสีวิทยาจาก MPR-CT กับผลการผ่าตัด พบว่าอัตราความแม่นยำเชิงผลบวก (positive predictive values) มีค่าเท่ากับ 77.7%, 75% และ 50% สำหรับ central canal stenosis, lateral canal stenosis และ foraminal stenosis ตามลำดับ ซึ่งมีค่าสูงกว่าใน disc herniation และ nerve root compression พบภาวะ typical claudication 10% ของผู้ป่วยและตำแหน่งที่พบการตีบแคบมากที่สุดได้แก่ กระดูก lumbar ที่ 4 ต่อกับกระดูก lumbar ที่ 5 (L4-L5)

จากการศึกษาพบว่า MPR-CT ซึ่งประกอบด้วยภาพ axial, coronal และ sagittal มีประโยชน์และมีความน่าเชื่อถือในการวินิจฉัยภาวะตีบแคบของช่องไขสันหลังระดับเอว

INTRODUCTION

Lumbar spinal stenosis is a pathologic condition which is defined as the reduction in diameter of the spinal canal including the central canal, lateral canal and neural foramina.[1] Degenerative stenosis is 10 times more common than developmental stenosis. The fundamentals of the disease were proposed by Verbiest[2-4] who first evaluated the size of spinal canal in developmental stenosis.

Degenerative lumbar spinal stenosis is the most frequent disease of the spine and is becoming a debilitating illness which causes chronic pain and difficulty in ambulation. It is caused by many factors, some of which include disc herniation, ligamentum flavum hypertrophy, facet joint hypertrophy, spondylolisthesis and compression fracture. More often the stenosis is caused by a combination of these factors.[5] More essential is to distinguish between spinal stenosis found incidentally on imaging studies and symptomatic spinal stenosis, because there is a poor correlation between the degree of stenosis and severity of symptoms.

The cheapest and most easy way to assess for imaging of lumbar spinal stenosis is radiograph. Radiographs are quite useful in evaluating patients for potential congenital and degenerative stenosis such as spondylolysis and spondylolisthesis. However the sensitivity and specificity of radiographs are quite low and further special imaging is still needed for the follow up of patient with lumbar spinal stenosis.

Therefore the imaging modalities in routine use for evaluating these conditions are computed tomography (CT), computed tomographic-myelography (CT- myelography) and magnetic resonance imaging (MRI). CT and MRI in particular have had dramatic technological improvements in spatial and contrast resolution. They have their own advantages and disadvantages although both modalities can adequately diagnose lumbar spinal stenosis. Interestingly, in most conditions the overall accuracy rate of each modality has been reported to be similar and even complementary.[6,7] In most literatures MRI is more preferable and doctors usually request imaging in particular MRI to reassure themselves. Also the ethical issue and patients' right make doctor avoid to be sued and do not want to miss the disease. However MRI is the expensive imaging modality in Thailand especially for the Government's thirty bahts health scheme.

Thornburg et al reported in his study of lumbar spinal stenosis diagnosed by MRI, CT-myelography and plain CT. He found no statistically significant difference in diagnostic accuracy among

these modalities. Thus the cost of examination, radiation dose and invasiveness should be considered to choose the imaging modality. Because of this, plain CT is the most cost effectiveness. Since multiplanar reconstruction (MPR)-CT has been developed and it is less expensive than MRI and less invasive than myelography, so we think the role of CT or MPR-CT should be reevaluated during current time of health care reform by government sector.[8-10]

Purpose

The purpose of this present work is to generally describe the initial experience of using multiplanar reconstruction computed tomography (MPR-CT) in the diagnosis of lumbar spinal stenosis and then to correlate our diagnosis with operative findings.

MATERIALS AND METHODS

Population

Patients with clinical diagnosis of lumbar spinal stenosis who came to the Department of Radiology, Siriraj Hospital for myelography and CT of lumbar spine.

Inclusion criteria

Currently we have to accept that MRI is routinely ordered by clinicians if lumbar spinal stenosis is suspected. But in this current time of economic depression, lumbar myelography is once again accepted to be a reasonable procedure instead of MRI or CT.

However lumbar myelography has some inherent limitations, e.g., complete myelographic block provides little or no information of pathology below or above the level of blockage, and in the scenario of undesirable subdural injection the accuracy in evaluation is lowered, and repeating lumbar myelography troubles the patient's feeling. So we have preferentially considered these as the initial criteria for including patients into this study. Therefore all our patients presented with complete or nearly complete myelographic block and subdural injection were chosen to undergo MPR-CT.

We identified 10 patients with clinically diagnosed lumbar spinal stenosis who met our selection criteria between July 2002 and December 2002 at the Department of Radiology, Siriraj Hospital. These patients included 7 females and 3 males, mean age 50.6 years old and age ranging from 24-69 years old. Examination with lumbar myelography and subsequent MPR-CT of these patients was carried out.

A correlation between features of MPR-CT findings and what was actually seen upon surgical exploration was done. In addition we also followed up the patients clinically for a time by reviewing the medical records or files.

Techniques

Routine examination included 5 mm thickness with 2 mm overlap slice thickness or contiguous 2 mm thickness with 1 mm overlap slice thickness produced high resolution axial and multiplanar sagittal and coronal CT images.

Axial images from mid portion of L2 vertebra to mid S1 sacral segment was done.

Additional images obtained depending on clinical history, information provided by requesting physician and results of scout view.

Reformatted images were obtained using bone and soft tissue windows to include entire neural foramen and central spinal canal.

This new spiral CT technology (PHILIPS) provided more rapid imaging capabilities of the lumbar spine, which may be helpful for imaging patients whose pain prevents them from remaining still for prolonged periods of time and may slightly compromise both spatial and contrast resolution. Image quality depends on patient immobility to prevent artifact formation. Faster scanners allow an entire routine examination to be performed within under 10 minutes and not difficult for most patients to maintain a single position for the period of time.

Contiguous sagittal and coronal reformation images (Figure 1) provide evaluation of the lumbar spine in complementary orthogonal plane, and software programming (EASY VISION) produces two sets of images, i.e. images emphasizing soft tissue details and images emphasizing bony details.

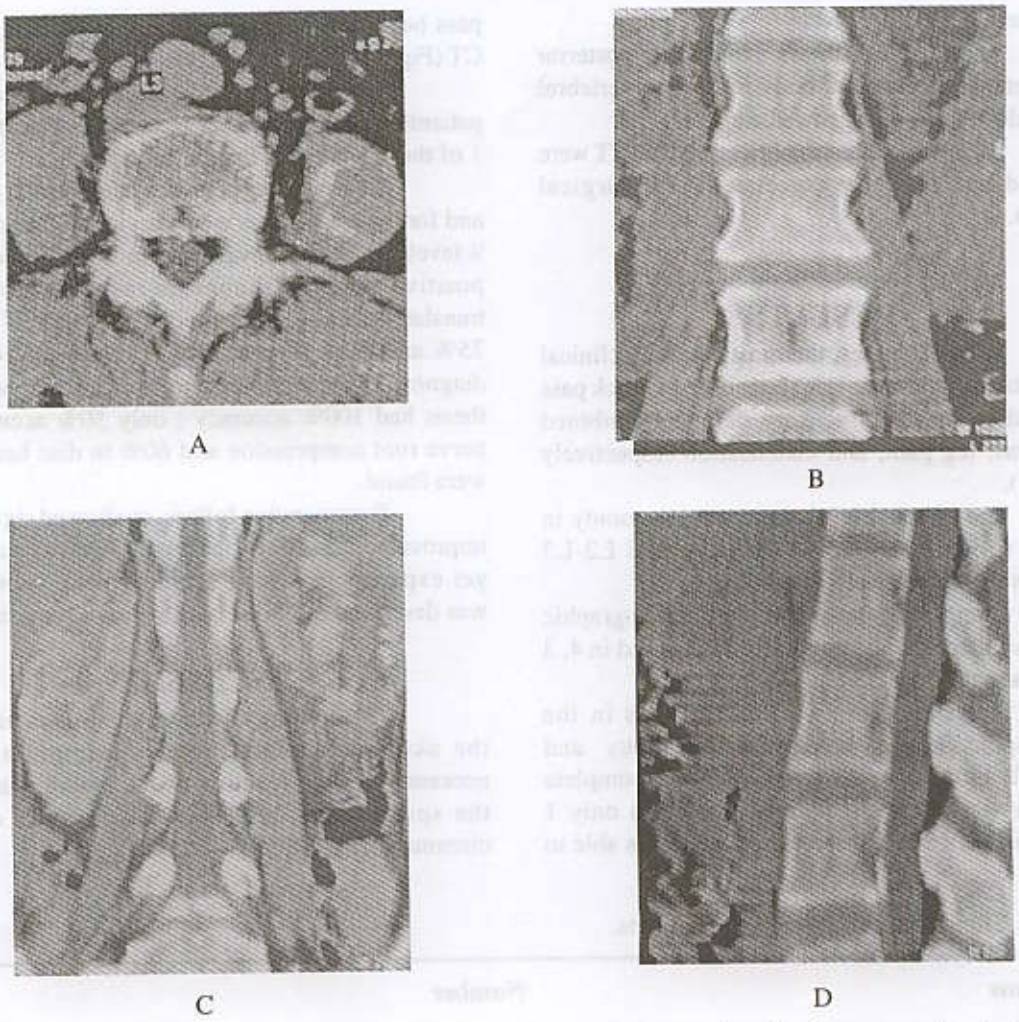


Figure 1. These figures show multiplanar reconstruction CT of lumbar spine. A is the conventional axial view. B-D are the reformatted coronal and sagittal views.

Imaging analysis

A board certified radiologist reviewed both lumbar myelography and MPR-CT obtained from these 10 patients. The clinical manifestations and MPR-CT including axial, sagittal and coronal views were evaluated.

The following variables were analyzed:

- Central canal stenosis : the AP diameter of spinal canal less than 10 mm.
- Lateral canal stenosis : the AP diameter of lateral canal less than 5 mm.
- Foraminal stenosis : narrow nerve root canal with loss of fatty tissue at any part surrounding nerve.
- Facet joint hypertrophy : facet joint shows arthritic change, joint space narrowing, joint hypertrophy and subchondral bone sclerosis.
- Ligamentum flavum hypertrophy : ligamentum flavum is fibroelastic structure that connects lamina and forms posterior wall of canal, hypertrophy when bulges inwards more than 2 mm especially if occurs bilaterallys.
- Disc herniation[12,13] : focal or diffuse protrusion of the disc component out of vertebral margin.
- Nerve root compression : nerve roots are displaced from their usual position with no fatty tissue separating between the nerves and surrounding

structures.

- Spondylolisthesis : anterior or posterior displacement of vertebral body relative to vertebral body below, leads to narrowed canal.

All levels of abnormalities on MPR-CT were assessed and properly correlated with surgical findings.

RESULTS

In our 10 cases, the most common clinical manifestation of lumbar spinal stenosis was back pain followed by motor or sensory deficits, combined symptoms, leg pain, and claudication respectively (Table 1).

The affected level was most commonly in L4-L5, followed by L5-S1, L3-L4, and L2-L3 respectively, respectively (Table 2).

Complete, nearly complete myelographic block and subdural injection were discovered in 4, 3 and 3 patients respectively.

However there were differences in the radiographic findings between myelography and MPR-CT. Lumbar myelography showed complete block in 4 patients but it truly existed in only 1 patient; in the other 3 the contrast agent was able to pass beyond the blockage levels when using MPR-CT (Figure 2).

Only 7 patients had surgery, and the other 3 patients received medical treatment. Unfortunately 1 of these 3 patients denied surgery.

Central canal stenosis, lateral canal stenosis and foraminal stenosis were surgically found in 7 of 9 levels, in 3 of 4 levels and in 1 of 2 levels with positive imaging diagnosis respectively which translated to a positive predictive value of 77.7%, 75% and 50% respectively (Table 3 and 4). The diagnosis of facet joint hypertrophy and spondylolisthesis had 100% accuracy ; only 50% accuracy in nerve root compression and 60% in disc herniation were found.

Postoperative follow up showed significant improvement in 5 of 7 patients. Two patients were yet experiencing long standing back pain which was described as failed back surgery syndrome.[14,15]

DISCUSSION

The concept of spinal stenosis is based on the assumption that there is minimum space necessary for the function of the neural content of the spinal canal, and that space, under certain circumstances, becomes too small.

Table 1. Clinical presentation of the patients.

Symptoms	Number
Back pain	5
Leg pain	1
Claudication	1
Motor or sensory deficit	3
Combined symptoms	3

Table 2. The affected levels of the lesions.

Affected level	Number
L4 - L5	5
L5 - S1	4
L3 - L4	2
L2 - L3	1

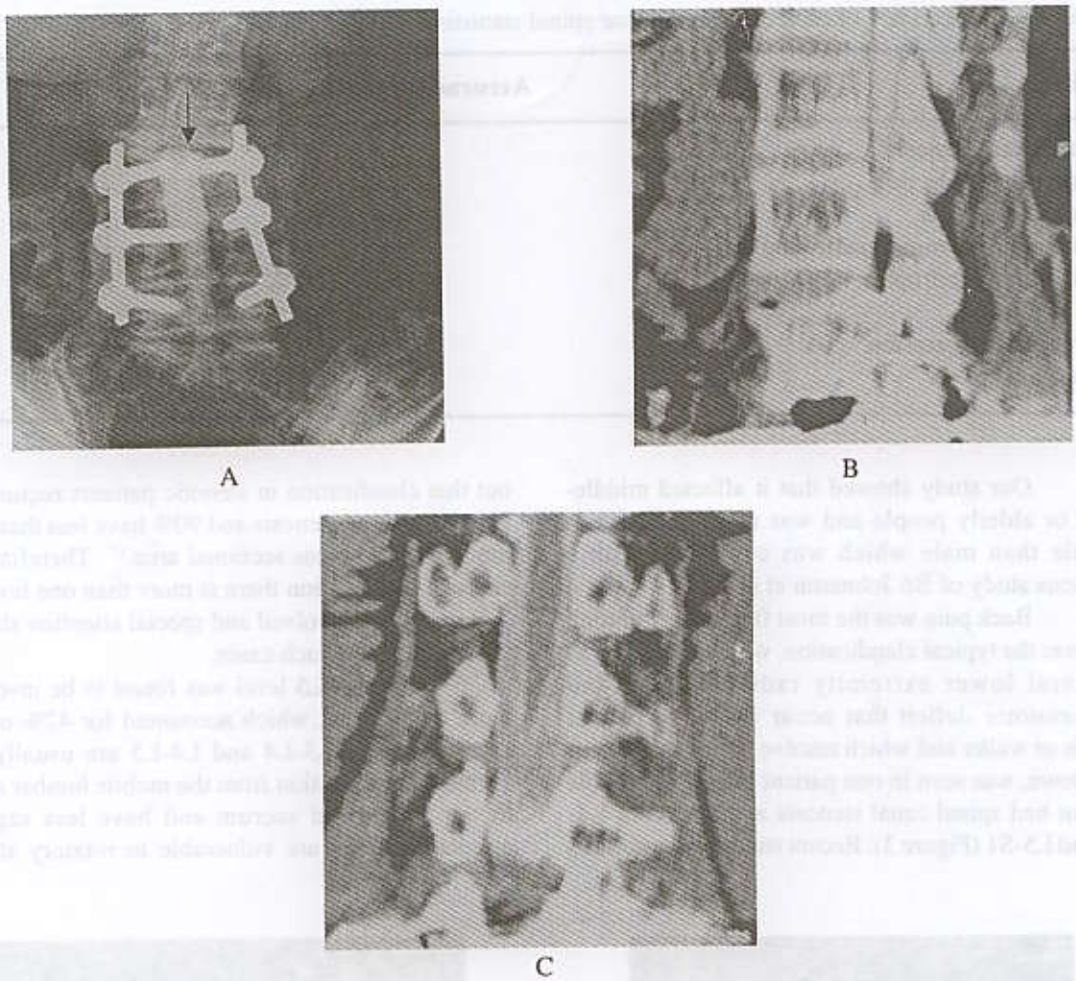


Figure 2. A 45 year- old man had surgery once many years ago for lumbar spinal stenosis and recently showed up with recurrent back pain. A is lumbar myelography of the patient which represents prior surgical instrumentation and complete block (arrow) at L2-L3. B and C are the reconstructed images indicating no evidence of complete block.

Table 3. Imaging and surgical findings of the studied patients.

Pathology	Imaging findings	Surgical findings
Central canal stenosis	9	7
Lateral canal stenosis	4	3
Foraminal stenosis	2	1
Ligamentum flavum hypertrophy	4	2
Facet joint hypertrophy	1	1
Disc herniation	10	6
Nerve root compression	10	5
Spondylolisthesis	1	1

Table 4. The accuracy of each defining lumbar spinal stenosis.

Findings	Accuracy or positive predictive value (%)
Central canal stenosis	77.70
Lateral canal stenosis	75
Foraminal stenosis	50
Ligamentum flavum hypertrophy	50
Facet joint hypertrophy	100
Disc herniation	60
Nerve root compression	50
Spondylolisthesis	100

Our study showed that it affected middle-aged or elderly people and was more common in female than male which was consistent with a previous study of Bo Johnsson et al.[16]

Back pain was the most frequent symptom, whereas the typical claudication, which is defined as bilateral lower extremity radicular pain and sensorimotor deficit that occur when the patient stands or walks and which resolve when the patient lies down, was seen in one patient in our study. This patient had spinal canal stenosis at the level of L4-L5 and L5-S1 (Figure 3). Recent studies have pointed out that claudication in stenotic patients requires at least 2 levels of stenosis and 90% have less than 100 mm square of cross sectional area.[17] Therefore, in cases of claudication there is more than one level of diseased spine involved and special attention should thus be given to such cases.

The L4-L5 level was found to be involved more than L5-S1, which accounted for 42% of the cases. Because L3-L4 and L4-L5 are usually the segments of transition from the mobile lumbar spine to the more rigid sacrum and have less sagittal orientation, they are vulnerable to rotatory strain.

Figure 3. A 47 year-old man developed typical claudication. A and B show central canal stenosis both L4-L5 and L5-S1 (arrows). Surgery confirmed the diagnosis.

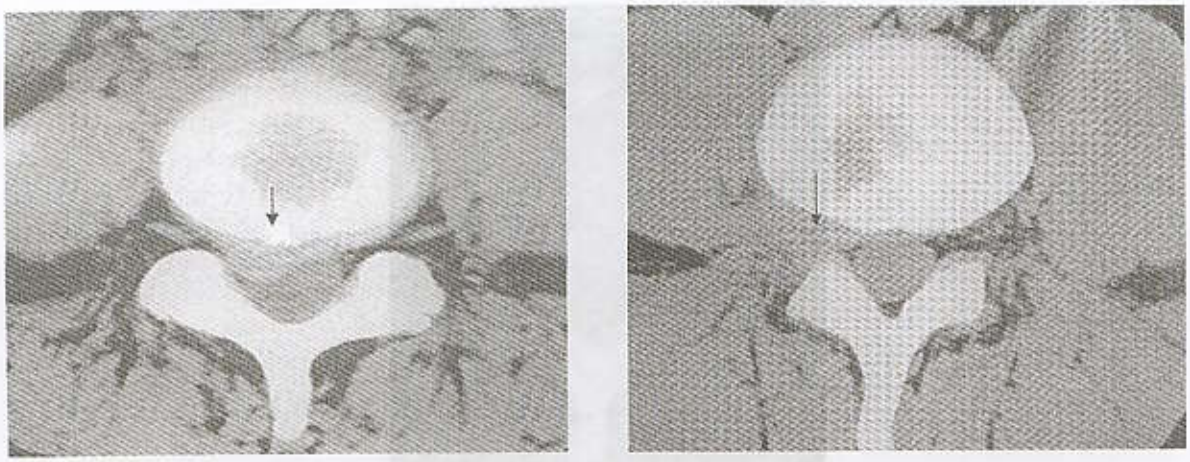


Figure 4. These figures depict disc material (arrow) showing higher attenuation than that of thecal sac and epidural fat. And the nucleus pulposus is darker in density as compared to annulus fibrosus.

While the L5-S1 segment is relatively protected from the injury because it lies below the intercrestal line and because of the relatively large transverse process of L5.[18]

Because most disc herniation occurs at the lower three levels, we therefore scan L2 through S1. In addition to soft tissue windows to evaluate the disc, bone windows are also routinely provided to evaluate stenosis, facet arthropathy and spondylolisthesis.

MPR-CT which is composed of reformatted axial, coronal and sagittal views has more advantages over the conventional axial view. The conventional axial view is routinely done with 5-10 mm slice thickness in our institution which is not appropriate for the evaluation of lumbar spinal stenosis. In addition some essential information might be overlooked. Furthermore the scan plane can not be properly adjusted in conventional CT.[19-22]

The partial volume averaging effect is less in MPR-CT because image reconstruction of any angle can be done on the suspected level of the lumbar spine. Moreover thin slice section can be done which is helpful in the evaluation of narrowed spinal canal of both osseous and soft tissue structures. Although the soft tissue evaluation capacity is not as excellent as that of MRI, this inferiority was offset in our study by using graded shade evaluation in a bid to differentiate soft tissue contrast based on its Housefield Units (H.U.) such as in disc herniation. Generally, disc material shows homogeneity with an attenuation of 80-100 H.U., which is greater than adjacent dural sac or epidural fat. The annulus fibrosus is slightly more dense because of higher collagen content than that of the nucleus pulposus, so we can diagnose disc herniation or nerve root compression by using this means (Figure 4).[23,24]

We also found that MPR-CT was outstanding in terms of providing more information in other planes. The entire course of the nerve root could be seen in a particular coronal view or sagittal oblique view (Figure 5). It was easier to diagnose foraminal stenosis in the sagittal view (Figure 6); the views of the other planes give the surgeon familiarity with the case.[25] The spondylolisthesis would not be mistaken as disc herniation or pseudodisc if evaluated by reformatted sagittal view.[26,27]

In our study, the CT could nicely depicted the central canal stenosis, lateral canal stenosis, facet joint hypertrophy and spondylolisthesis because of direct images of spinal canal or osseous details. However, the positive predictive values of disc herniation, ligamentum flavum hypertrophy and nerve root compression were quite low, though we used soft tissue graded shade evaluation to distinguish between ligaments, nerve roots, free fat and herniated disc material. Forristall et al studied MRI and CT of patients with disc herniation in

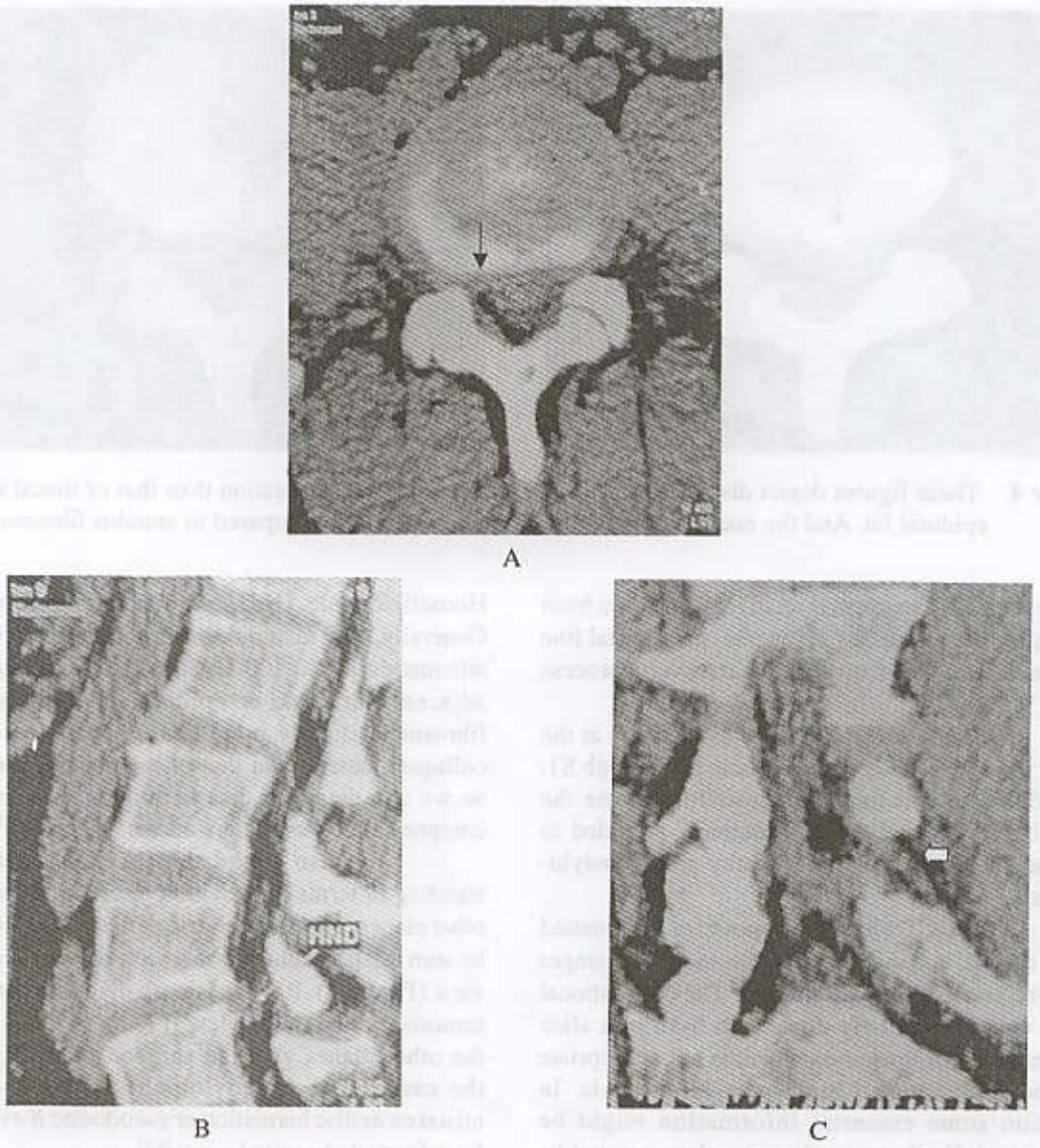
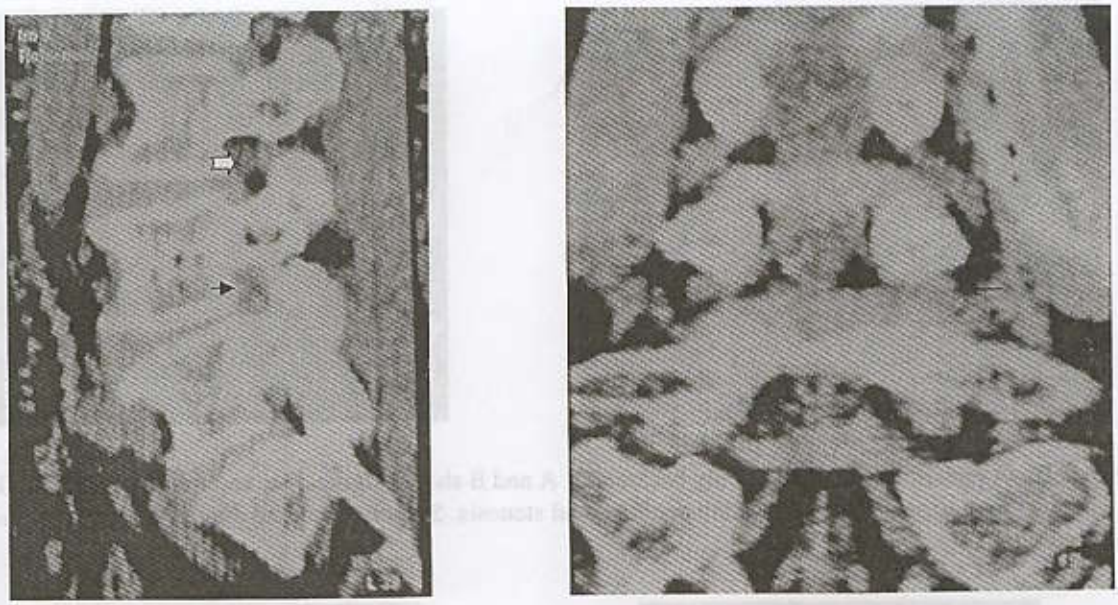


Figure 5. A 60 year-old woman had low back pain. A and B show disc herniation but this patient had no nerve root compression. C, the sagittal oblique view could be done which demonstrated the normal course of nerve root (open arrow).

comparison and correlation with surgical findings. They found that surgery reported MRI diagnostic more than CT with accuracy of 90.3% and 77.4% respectively. The sensitivity and specificity of MRI were 91.7% and 100% and of CT were 83.3% and 71.4% respectively; and using soft tissue graded evaluation was somewhat subjective criteria. We expected that the positive predictive value for foraminal stenosis should be high because the bony or osseous element was being evaluated. The proposed reason was the foraminal stenosis was assessed by reconstructed sagittal view which might have some mistakes as compared to central canal and lateral canal which were evaluated by axial plane.



A B

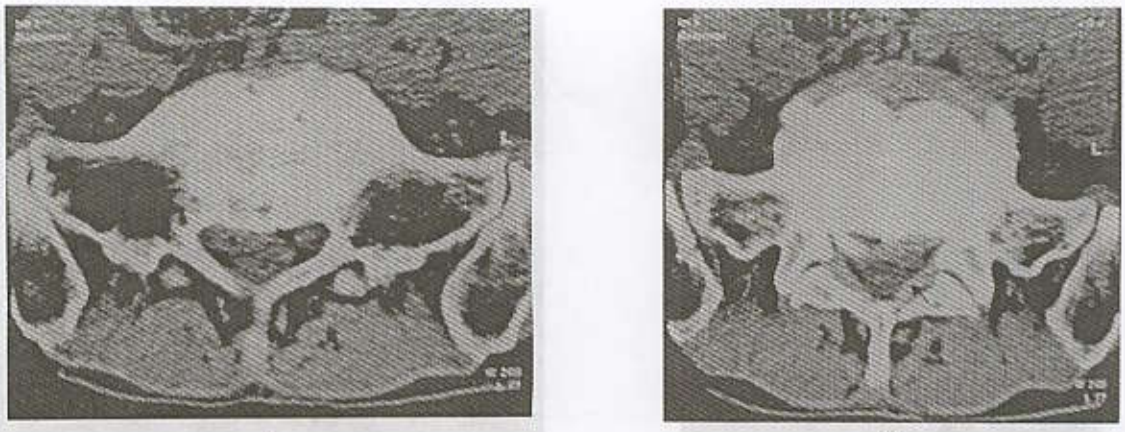
Figure 6. The elderly man with lumbar spinal stenosis. A. Sagittal reconstruction shows left L4 foraminal stenosis (arrow) compared to left L3 nerve root (open arrow) which lies freely inside the foramina and is surrounded by fat seen as hypodensity. B. is the coronal reconstruction at the same level, left L 4 (arrow). The surgery was consistent with imaging findings.

Because we thought that the quality of the reconstructed images would not be better than the quality of initial axial CT image data so the spatial resolution might be lost.

We assumed that the contrast agent was not needed both intravenously and intrathecally because it did not affect the imaging interpretation.

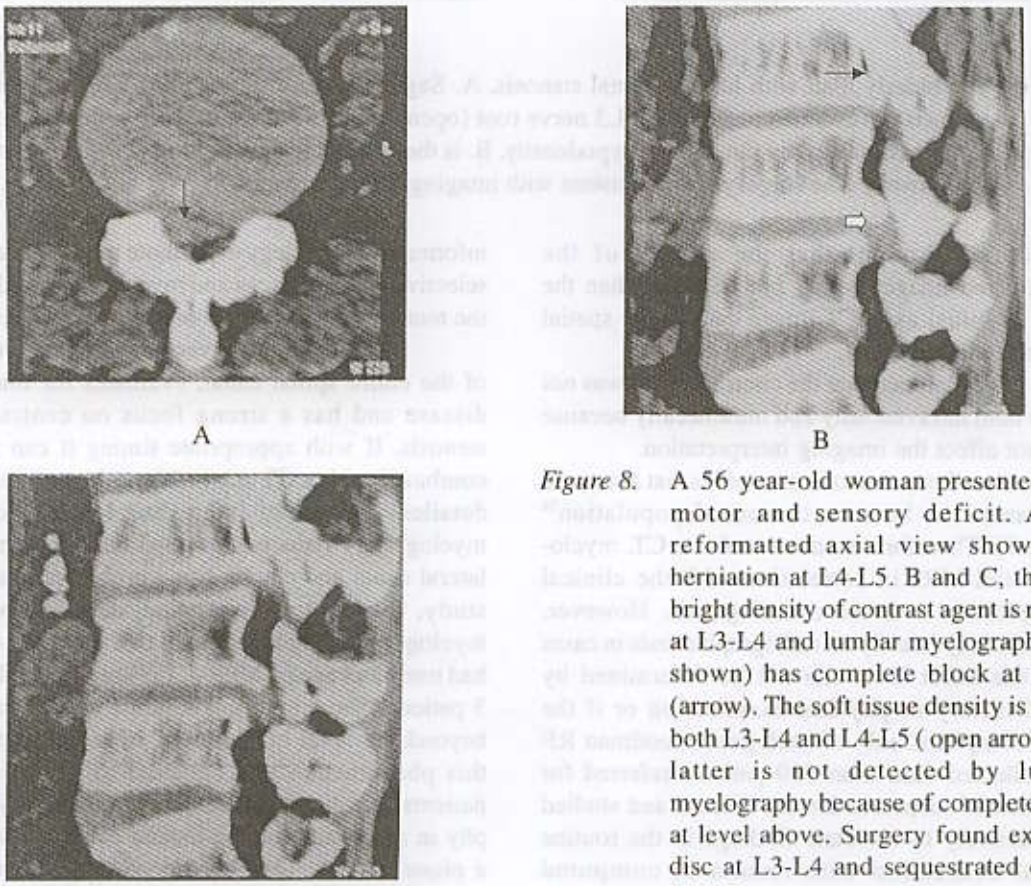
Another point to be stressed is that a stenotic appearance can be seen in normal population[28] (Figure 7). Therefore we must evaluate CT, myelography and MRI in correlation with the clinical manisfestation to avoid overdiagnosis. However, physicians rely heavily on radiographic tests in cases where the exact level can not be determined by clinical history or physical examination or if the patient complains only of back pain. Goodman RE et al collected data from 339 patients referred for evaluation of suspected lumbar disease and studied retrospectively to correlate findings in the routine clinical evaluation with results of computed tomography and myelography, using the accurate clinical features they suggested that a good clinical information or strategy to promote more efficient and selective use of CT scan and myelogram could reduce the number of myelogram order by more than 50%.

Myelography gives an excellent overview of the entire spinal canal, evaluates for multilevel disease and has a strong focus on central canal stenosis. If with appropriate timing it can also be combined with a CT scan adding the possibililty of detailed analysis of interesting levels. However, myelography reduces the potential concerning the lateral canal and causes some problems like in our study, out of 4 patients that showed complete myelographic block we found that only one of them had true blockage on MPR-CT (Figure 8). In the other 3 patients, the intrathecal contrast agent could pass beyond the level of blockage. The explanation for this phenomenon was believed to stem from the patients' position, because during doing myelography in our institution the patient exclusively lied in a prone position. The fluoroscopic table was adjusted to ascertain that the patient had real blockage and the patient never moved to another position. But to



A B

Figure 7. A patient complained of only back pain. A and B show bulging disc and mild ligamentum flavum hypertrophy (arrow) causing central canal stenosis. Surgery found no abnormality at this level.



A B C

Figure 8. A 56 year-old woman presented with motor and sensory deficit. A, the reformatted axial view shows disc herniation at L4-L5. B and C, the very bright density of contrast agent is noticed at L3-L4 and lumbar myelography (not shown) has complete block at L3-L4 (arrow). The soft tissue density is seen at both L3-L4 and L4-L5 (open arrow), the latter is not detected by lumbar myelography because of complete block at level above. Surgery found extruded disc at L3-L4 and sequestrated disc at L4-L5.

perform CT, the patients were lying down on their backs, therefore we believe that during the procedure the contrast agent possibly could pass through where was myelographically assumed true blockage. Another possible explanation was that the CT showed higher contrast than did the myelography and thus it was easier to diagnose true blockage. In addition myelography is an invasive method, and it has been abandoned in some centers.

Limitation

The limitations of our study were that the number of patients enrolled in this study was small and the negatively interpreted levels were not surgically explored, hence the sensitivity, specificity and negative predictive values were unable to be calculated.

CONCLUSION

Examination of patients with spiral CT is one of the main and most available means to diagnose degenerative lumbar spinal stenosis. Spiral CT possesses high speed of scanning, possibility to examine the spine at a considerable length and to obtain high quality reconstructions or multiplanar reformation. Thus it allows visualization not only bone tissue but also soft tissue abnormality eventhough it is less accurate than MRI.

MPR-CT is superior in delineating osseous structures, relatively cost effective as compared to MRI. MRI is greater and less invasive than myelography. It is not necessary to give the contrast agent by both intravenous and intrathecal routes.

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