MRI EVALUATION ON
EXIT FORAMINA AND LATERAL RECESS
IN PATIENTS WHO UNDERGO
POSTERIOR LUMBAR INTERBODY FUSION
IN HOSPITAL RAJA PEREMPUAN ZAINAB II

By:

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MAGNETIC RESONANCE IMAGING (MRI) EVALUATION ON LATERAL RECESS AND EXIT FORAMINA IN PATIENTS WHO UNDERGO POSTERIOR LUMBAR INTERBODY FUSION (PLIF) IN HOSPITAL RAJA PEREMPUAN ZAINAB II (HRPZ II)

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Introduction: Magnetic Resonance Imaging (MRI) is the gold standard imaging modality for investigation of degenerative disc disease. Changes of degenerative discs are well-demonstrated. Disc dessication and herniations, thickened ligamentum flavum and osteophytosis cause narrowing of neuroforamina, and further compromise the spinal cord and exiting nerve roots. Posterior Lumbar Interbody Fusion (PLIF) is a surgical technique of nerve root decompression using posterior approach. In PLIF procedure, laminectomy is done to gain access to the intervertebral disc space. Discectomy is then performed and disc materials are replaced with disc spacer to restore disc height. It was postulated that PLIF procedure is able to restore foraminal height and therefore relieved nerve root compression without foraminotomy.

Objectives: To study the improvement of exit foramina and lateral recess stenosis in patients with back pain who underwent Posterior Lumbar Interbody Fusion (PLIF), using MRI as diagnostic tool, to correlate the MRI findings with clinical symptoms and to determine whether disc spacer height is a good predictor for improvement of lateral recess and exit foramina.

Methodology: This is a cross-sectional, observational study of patients with degenerative disc disease who underwent Posterior Lumbar Interbody Fusion (PLIF) in Hospital Raja Perempuan Zainab II from June 2007 till June 2010. Patients' clinical symptoms were assessed using Oswestry Disability Index (ODI) pre- and post- procedure. MRI lumbosacral pre and post PLIF were analysed in axial and sagittal views. The depth of the lateral recess and exit foramina were measured at mid zone, exit zone and far lateral zone, and compared pre and post PLIF. The height of the disc spacer was measured at mid sagittal views. Mean difference of lateral recess and exit foramina size before and after procedure were analysed using paired t-test, and correlated with ODI score using Pearson's correlation test. Correlation test was also used to determine whether disc spacer height is a good predictor for improvement of lateral recess and exit foramina size.

Results: From 39 patients underwent PLIF in Hospital Raja Perempuan Zainab II, 25 patients fulfilled the inclusion criteria with 43 lumbar segments available for analysis. Increment of lateral recess and exit foramina measurements post PLIF were observed at all levels which was statistically significant ($p<0.05$). Improvement of clinical symptoms based on ODI score ($p<0.05$) was also noted. However, there was no significant correlation between patients clinical improvement and improvement of lateral recess and exit foramen ($p>0.05$).

It was also noted that the height of the disc spacer was not a predictor for increment of exit foramen ($p>0.05$)

Conclusion: Posterior Lumbar Interbody Fusion is proven to restore depth of lateral recess and exit foramen. Patients underwent PLIF had significant good surgical outcome. The difference of disc spacer height used in the procedure did not determine the increment of exit foramina. Therefore, current practice of using disc spacer height according to adjacent disc height is an acceptable method.

Dr. Juhara Haron: Supervisor

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IN LEGEND HOTEL, KUALA LUMPUR

ON 9th and 10th APRIL 2011

To:

my husband, MOHD AZREEN , who have been so patience and encouraging,

my children, LUQMAN HAKIM, ABDUL HAFIZ, MUHAMMAD FATTAH,

and NUR HANNAN , my little sunshine who gave me strength,

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my brothers and sisters, IDA, HAZMI, ARFAH, MOHAIMIN,

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ABBREVIATIONS

AP	Anteroposterior
CI	Confidence Interval
cm	centimeter
CT	Computed tomography
IAP	Inferior articular process
LSS	Lumbar spinal stenosis
MRI	Magnetic resonance imaging
MRM	Magnetic resonance myelogram
ODI	Oswestry Disability Index
PD	Proton density
PLIF	Posterior lumbar interbody fusion
SAP	Superior articular process
SD	Standard deviation
TE	Time to echo
TR	Time to repetition

Abstrak

Bahasa Melayu

Tajuk:

Penilaian Magnetic Resonance Imaging (MRI) kepada liang-liang saraf (lateral recess dan neuroforamina) terhadap pesakit yang bermasalah sakit tulang belakang degeneratif dan menjalani Posterior Interbody Lumbar Fusion (PLIF) di Hospital Raja Perempuan Zainab II (HRPZ II).

Latar Belakang:

Sakit tulang belakang disebabkan proses degeneratif merupakan salah satu keluhan klinikal yang paling umum di kalangan pesakit di klinik pesakit luar dan ortopedik. Sementara kebanyakan kes biasanya sembuh dalam tempoh beberapa minggu, 2% daripada mereka mempunyai tanda-tanda radikulopati dan memerlukan penyiasatan radiologi yang lebih lanjut. Tanpa mengira usia dan pekerjaan pesakit, kesakitan tulang belakang merupakan penyebab umum ketidakupayaan sehingga memberikan kesan besar kepada kehidupan peribadi dan sosial individu dan keluarga,dan beban ekonomi kepada masyarakat.

Magnetic Resonance Imaging (MRI) adalah modaliti standard untuk penyiasatan penyakit tulang belakang degeneratif kerana kebolehannya mempamerkan kontras tinggi terhadap tisu lembut, kemampuan pengimejan multiplanar dan tidak melibatkan radiasi pengionan. Perubahan imej degeneratif disk intervertebra adalah jelas, di mana herniasi disk, penebalan ligamentum flavum dan pembentukan tulang baru

menyebabkan penyempitan kepada neuroforamina, dan selanjutnya memberi kompromi terhadap akar saraf yang keluar. Oleh itu, penilaian MRI amat bernilai untuk menentukan segmen tulang belakang yang terlibat dan tahap penyempitan neuroforamina. MRI juga digunakan sebagai panduan untuk membantu perancangan pembedahan dekompresi saraf –saraf akar. Posterior Interbody Lumbar Fusion (PLIF) merupakan satu teknik pembedahan pada disk degeneratif di mana ianya dipostulatkan boleh mengembalikan kedalaman neuroforamina kepada tahap lebih baik.

Objektif:

Untuk menilai peningkatan kedalaman liang saraf (lateral recess and neuroforamina) pada pesakit yang mengalami sakit tulang belakang dan menjalani Posterior Interbody Lumbar Fusion (PLIF), dengan menggunakan MRI sebagai alat diagnostik, untuk mengkorelasikan penemuan MRI dengan gejala klinikal dan untuk menentukan sama ada ketinggian alat ganti disk adalah prediktor untuk peningkatan liang saraf.

Metodologi:

Ini adalah kajian keratan lintang terhadap pesakit yang mengalami sakit tulang belakang akibat penyakit degeneratif disk yang menjalani Posterior Interbody Lumbar Fusion (PLIF) di Hospital Raja Perempuan Zainab II dari bulan Jun 2007 hingga Jun 2010. Tahap ketidakupayaan dan kesakitan pesakit diukur menggunakan Oswestry

Disability Index (ODI). MRI lumbosakral pra dan pasca PLIF dianalisis dalam pandangan paksi (axial) dan sagital. Kedalaman neuroforamina diukur pada tiga zon: zon tengah, zon keluar dan zon paling jauh. Ketinggian alat ganti disk diukur pada pertengahan pandangan sagital.

Keputusan:

Dari 39 pesakit menjalani PLIF di Hospital Raja Perempuan Zainab II, 25 pesakit yang memenuhi kriteria inklusi dengan 43 segmen lumbar sedia untuk dianalisa. Penilaian lateral reses dan neuroforamina pasca pengukuran PLIF mendapati terdapat peningkatan kedalaman di semua zon yang secara statistik bermakna ($p < 0.05$). Perubahan signifikan gejala klinikal berdasarkan skor ODI ($p < 0.05$) juga direkodkan. Namun, tidak ada hubungan yang signifikan antara pembaikan klinikal pesakit dengan peningkatan lateral reses dan neuroforamina ($p > 0.05$). Kajian ini juga mendapati bahawa ketinggian alat ganti disk bukan merupakan prediktor untuk peningkatan neuroforamina ($p > 0.05$).

Kesimpulan:

Posterior Lumbar Fusion Interbody terbukti dapat mengembalikan kedalaman lateral reses dan neuroforamina. Pesakit yang menjalani pembedahan PLIF mempunyai penyembuhan yang signifikan baik. Perbezaan ketinggian alat ganti disk yang digunakan dalam prosedur tidak menentukan peningkatan kedalaman neuroforamina .

Oleh kerana itu, amalan kini mengukur ketinggian alat ganti disk berdasarkan ketinggian disk intervertebra yang berdekatan adalah dianggap kaedah yang boleh diterima pakai.

Abstract

English

Title:

Magnetic Resonance Imaging (MRI) Evaluation on Lateral Recess and Exit Foramina in Patients Who Undergo Posterior Lumbar Interbody Fusion (PLIF) in Hospital Raja Perempuan Zainab II (HRPZ II)

Background:

Low back pain due to degenerative lumbar spine is one of the most common presenting complaints in out-patient and orthopaedic clinics. While most cases usually resolve in few weeks, 2% of them develop radiculopathy and need further radiological investigations. Regardless of age and occupation of patients, back pain is a common cause of disability and gives a great personal and social impact to the individual and families, and economic burden to the society.

Magnetic Resonance Imaging (MRI) is the gold standard imaging modality for investigation of degenerative disc disease for its superior soft tissue contrast, multiplanar imaging capability and non-ionizing property. Changes of degenerative intervertebral discs are well-demonstrated. Disc herniations, thickened ligamentum flavum and osteophytosis cause narrowing of neuroforamina, and further compromise the spinal cord and exiting nerve roots. Therefore, MRI is valuable to determine the degree of stenosis and level of compression, and hence, used as a guide to aid plan of surgical decompression.

Posterior Lumbar Interbody Fusion (PLIF) is one of the surgical technique of nerve root decompression using posterior approach. In PLIF procedure, incision is made at midline at the back. This is followed by laminectomy to gain access to the intervertebral disc space. Discectomy is then performed and disc materials are replaced with disc spacer to restore disc height. It was postulated that PLIF procedure is able to restore foraminal height and therefore relieved nerve root compression without foraminotomy.

Objectives:

To study the improvement of exit foramina and lateral recess stenosis in patients with back pain who underwent Posterior Lumbar Interbody Fusion (PLIF), using MRI as diagnostic tool, to correlate the MRI findings with clinical symptoms and to determine whether disc spacer height is a good predictor for improvement of lateral recess and exit foramina.

Methodology:

It is a cross-sectional, observational study of patients with back pain due to degenerative disc disease who underwent Posterior Lumbar Interbody Fusion (PLIF) in Hospital Raja Perempuan Zainab II from June 2007 till June 2010. Patients' clinical symptoms were assessed using Oswestry Disability Index (ODI) pre- and post-procedure. MRI lumbosacral pre and post PLIF were analysed in axial and sagittal views. The depth of the lateral recess and exit foramina were measured at mid zone, exit zone and far lateral zone, and compared pre and post PLIF. The height of the disc

spacer was measured at mid sagittal views. Mean difference of lateral recess and exit foramina size before and after procedure were analysed using paired t-test, and correlated with ODI score using Pearson's correlation test. Correlation test was also used to determine whether disc spacer height is a good predictor for improvement of lateral recess and exit foramina size.

Results:

From 39 patients underwent PLIF in Hospital Raja Perempuan Zainab II, 25 patients fulfilled the inclusion criteria with 43 lumbar segments available for analysis. Increment of lateral recess and exit foramina measurements post PLIF were observed at all levels which was statistically significant ($p<0.05$). Improvement of clinical symptoms based on ODI score ($p<0.05$) was also noted. However, there was no significant correlation between patients clinical improvement and improvement of lateral recess and exit foramen ($p>0.05$). It was also noted that the height of the disc spacer was not a predictor for increment of exit foramen ($p>0.05$)

Conclusion:

Posterior Lumbar Interbody Fusion is proven to restore depth of lateral recess and exit foramen. Patients underwent PLIF had significant good surgical outcome. The difference of disc spacer height used in the procedure did not determine the increment of exit foramina. Therefore, current practice of using disc spacer height according to adjacent disc height is an acceptable method.

1.0 INTRODUCTION

Low back pain is one of the most common presenting complaints in the out-patient and orthopedic clinics. Most of these cases present with non-specific low back pain which usually resolves in a few weeks. These patients usually need reassurance, rest from work and conservative management. However, when back pain is associated with radiculopathy, it warrants further investigations (Michelle, 2009). A study by Veerapen *et al.,* (2007) revealed 11.6% out of 2600 populations in a semirural area, Malaysia were diagnosed with low back pain problem. Another study by Nurul Izzah Abdul *et a.,l* (2010) showed that the prevalence of low back pain among primary school teachers in Malaysia was 40.4%. A study in Canada and North America proved that low back pain was the leading cause of disability and morbidity in middle-aged person which was by far the most expensive source of workers' compensation costs (Manga *et al.*, 1993). Therefore, regardless of age and occupation of patients, back pain gives a great personal and social impact to the individual and families, and economic burden to the society.

Plain radiograph still serve as the initial primary investigation in patients with low back pain (Tan, 2003). It is good in demonstrating bony details and intervertebral disc space height. The changes of degenerative spine is well-demonstrated on plain radiograph, this includes osteoporosis, sclerosis of endplates, osteophyte formation, reduction of disc height, vacuum disc phenomenon, spinal canal and foramina narrowing and presence of spondylolisthesis. Even though it lacks soft tissue details, it is sufficient in most cases when the patient only need conservative or medical management. It is also a good imaging modality in follow-up of these patients.

When conservative and medical management failed, patient may then need to be further evaluated for possibilities of surgical decompression to relieve the symptoms. In these situations, other radiological investigations then play important roles and are used to further investigate the lumbar levels involved as well as to evaluate the degree and severity of the disease.

Myelogram, Computed Tomography (CT) scan, CT myelogram and MRI can be used in the investigations of degenerative disc disease with nerve roots or spinal cord involvement (Kenneth and Hesselink, 1997). Depending upon availability of the resources, examination time, benefits, invasiveness of the procedures, advantages and disadvantages, as well as indications and contraindications, choice of modality used in the investigations of patients with low back pain who may benefit from surgical decompression should be discussed, justified and agreed between the radiologists and the managing team.

Magnetic Resonance Imaging (MRI) is one of the most important radiological investigations in patients with low back pain. It is the gold standard modality for visualizing disc pathology, which is the primary event in degenerative spine leading to foramina stenosis and nerve root impingement. It is superior compared to other imaging modalities because of its non-ionizing radiation property, ability to demonstrate excellent soft tissue contrast and non- invasive. It is also known for its high resolution, multiplanar imaging capability. It is relatively a safe and fast examination provided that all the precautions are well taken care of.

However, the use of MRI in the investigation of non-specific low back pain is discouraged and should be reserved only to those with severe or progressive neurological deficit, or for those cases in which serious underlying pathology is suspected. The MRI findings of disc bulges or protrusions in people with low back pain may frequently be coincidental (Jensen *et al*, 1994). The high prevalence of asymptomatic disc degenerations must be taken into account when MRI is used for assessment of spinal symptoms (Powell *et al*, 1986)

At present, MRI is the primary and preferred radiological investigation in deciding management plan for patients with degenerative disc disease requiring surgery. It is the modality of choice in pre-operative assessment of spinal stenosis and nerve root impingement. It is used to determine the lumbar levels involved and severity of the disease, and later, as a guide to the managing team in planning the surgical approach and procedures. Its role in planning surgical management is well acknowledged in cases with radiculopathy and spinal stenosis (N J Sheehan, 2010)

There are various surgical procedures practiced worldwide to decompress the nerve roots impingement in degenerative lumbar spine. Posterior Lumbar Interbody Fusion (PLIF) is a surgical decompression procedure that is been practiced in HRPZ II. In PLIF surgery, the spine is approached in the midline posteriorly, and laminectomy is performed to allow visualization of the nerve roots. The nerve roots are then retracted to one side and the disc space is cleaned of the disc material. An interbody spacer, made of carbon fiber, together with a bone graft, is then inserted into the disc space.

It is postulated that the interbody spacer inserted into the disc space will restore the disc height, and thereby, indirectly restore the foraminal height and release the nerve root compression.

Fusion rates in PLIF surgery are higher (90% -95%) than posterolateral fusion rates (Peter F Ullrich, 2004). This is because bone graft is inserted into the anterior portion of the spine, where there is more surface area. Furthermore, this bone is under compression, and thus heals better. Non-union rates are higher in patients who have had prior spine surgery, had multiple level fusion surgery, those who smoke or obese, and those with history of cancer and being treated with radiation. Other than non-union, the risks of PLIF procedure include infection and bleeding, which are fairly uncommon, occurring about 1% - 3%.

Post-operatively, patients are assessed for recovery and success of surgical procedure based on clinical assessment and plain radiograph. MRI examination is not a routine assessment in patients who underwent surgical decompression for nerve root impingement, unless there are symptoms suggestive of complications and failed back surgery, such as infections or failure of instrumentation.

With the postulation that PLIF procedure is able to restore foraminal height and therefore, released nerve root compression, this study is aimed to determine the change in size of exit foramina and lateral recess measurement after PLIF using MRI as imaging tool. These changes will be correlated with clinical outcome. It will try to determine whether different height of the disc spacer is a good predictor to improvement of exit foramina and lateral recess stenosis.

2.0 LITERATURE REVIEW

2.1 BACKGROUND

About 70% - 85% population will experience low back pain at some time in their life. Annual incidence of low back pain is estimated at 5%, but only 1% will develop radiculopathy (Nick Harden *et al.*, 2005). Fortunately, the low back pain resolves in the vast majority within two to four weeks (McKeon *et al*., 2006).

For individuals younger than 45 years old, back pain represents the most common cause of disability and is generally associated with a work-related injury. For individuals older than 45 years old, back pain is the third common cause of disability. Determining the cause of low back pain is not easy. It is often multifactorial that contributes to back pain. Radiological investigations often needed to further reveal the cause of the pain, whether it is developmental, traumatic, infective or degenerative in origin. Anatomical abnormalities are also common in spine that it should not necessarily translate into clinical symptoms. Therefore, a careful clinical history and physical examination are vital to evaluation, treatment and management of patient.

2.2 ANATOMY AND FUNCTION

Lumbar spine is made up of five vertebrae, referred as L1 to L5 (Figure 1). It provides skeletal support for the human body and responsible for the distribution of axial loads. These vertebrae bear much of the body's weight and related to biomechanical stress. For these reasons too, the lumbar vertebrae are more subjected to trauma and degenerative diseases. Thus, the lumbar vertebral bodies are taller and bulkier compared to the rest of the spine.

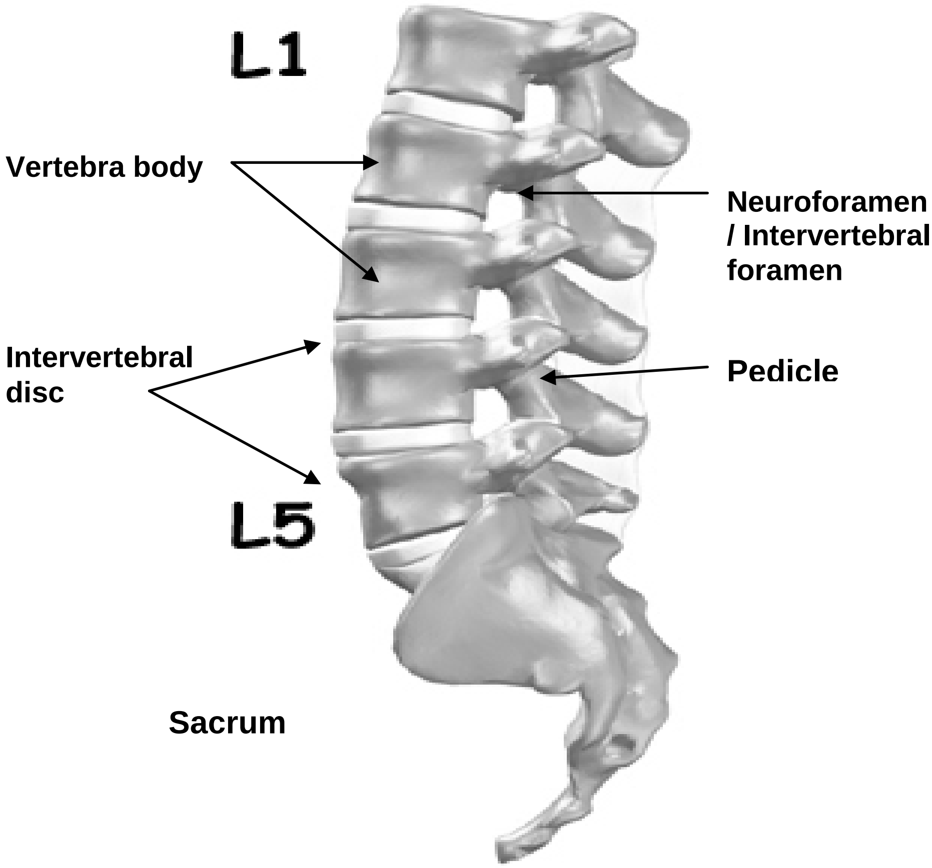
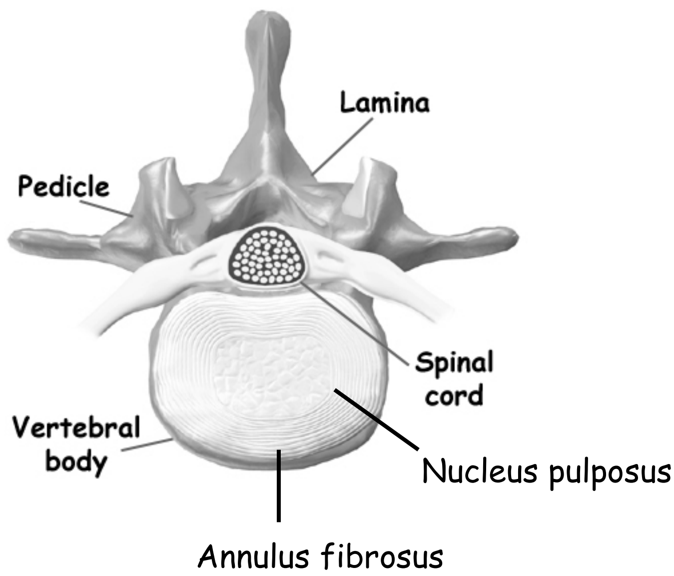


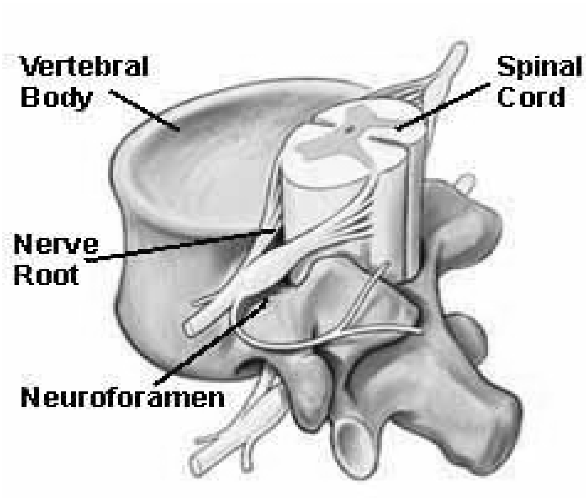
Figure 1 : The lumbar vertebra

Adopted from *Spine Universe*, Stewart G, 2010.

Each lumbar vertebra is composed of a vertebra body, two pedicles, two laminae and a spinous process. The arrangement of these structures formed a bony ring called as spinal canal. The vertebral structures and intervertebral discs protect the spinal cord and spinal nerve. The spinal cord is protected within the spinal canal. The pedicles and laminae provide protective roof over the spinal nerves. (Figure 2).



(a) Axial view



(b) Lateral oblique view

Figure 2 : Structure of a lumbar vertebra body

Adopted from *Spine Universe,* Stewart G, 2010.

Rauschning W (1987) and Lee et al (1998) describes three clinically important part of intervertebral canal: the entrance zone (lateral recess area), the mid zone (sublamina blind area) and the exit zone (near the intervertebral foramen) (Figure 3).

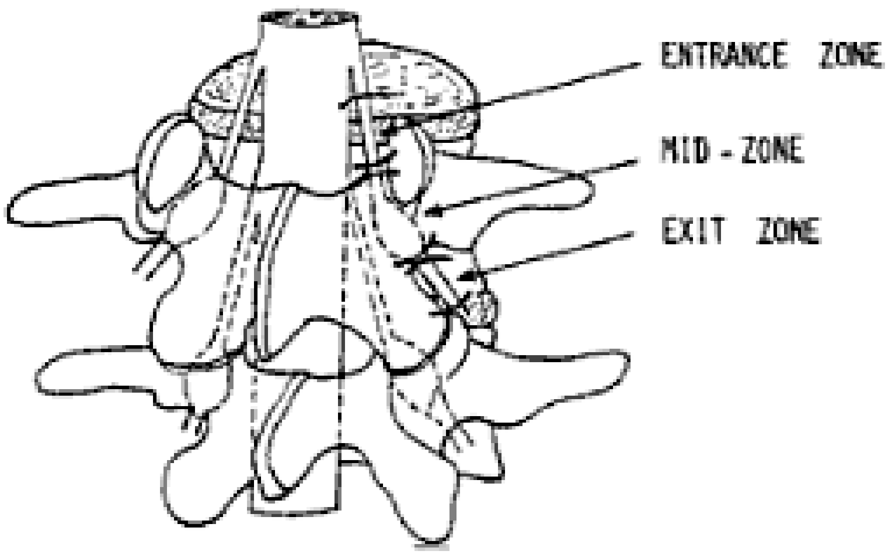


Figure 3 : The three zones of the intervertebral canal of the lumbar spine

Adopted from the *Spine*, Rauschning W (1987).

The spinal nerve exits the spinal canal through a foramen (figure 4). The foramen through which the spinal nerves exit the spinal canal is called as intervertebral foramen or exit foramen or neural foramen. Anatomically, it is bounded by the vertebral body and intervertebral discs anteriorly, the superior facet of the lower vertebra posteriorly, and above and below by the pedicles of adjacent vertebrae (Kenneth and Hesselink, 1997). The normal intervertebral foramen measures more than 4 mm in anteroposterior (AP) diameter (Stephanie Ryan, 2004).

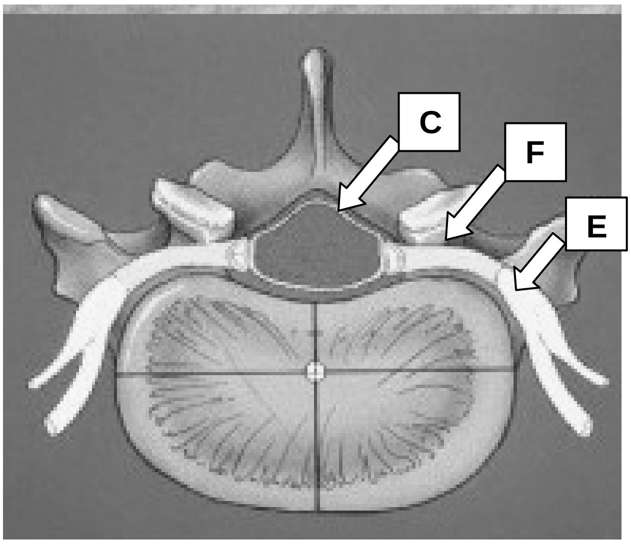


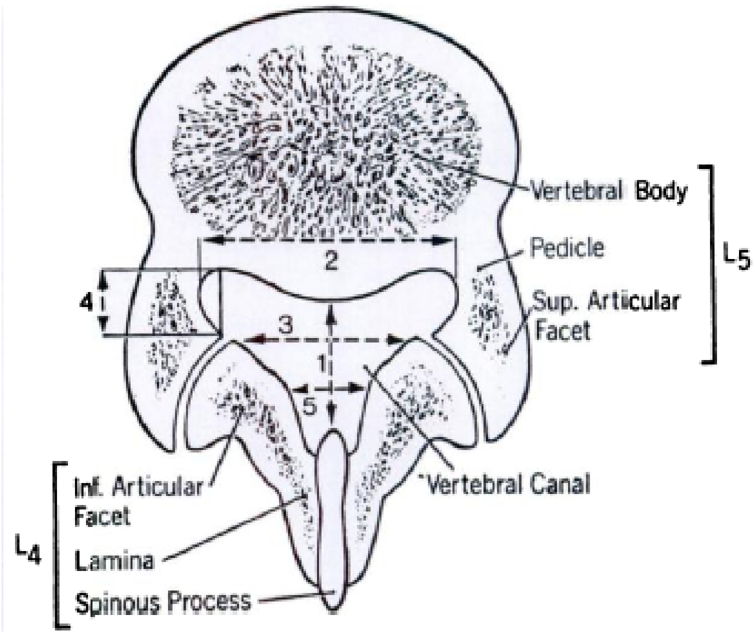
Figure 4: The spinal canal zones demonstrated in axial plane.

C : central zone, F : foraminal zone. E : extraforaminal zone

Adopted from the *Spine*, Rauschning W (1987).

The anterolateral portion of the spinal canal where the descending nerve root lies is called the lateral recess. Anatomically, the lateral recess is an area bordered anteriorly by the posterior surface of the vertebral body, posteriorly by the superior articular facet and laterally by the pedicle. It is funnel-shaped, narrowest at its cephalic portion at the superior border of the pedicle.

The spinal nerve root leaves the dural tube, descends obliquely downward and outward through the lateral recess, and emerges under the pedicle via the foramen. The depth of the lateral recess should be measured between the most anterior portion of the superior articular facet and the posterior border of the spinal canal at the superior margin of the pedicle (Figure 5). The normal lateral recess measures more than 5 mm in its depth (Michael A Mikhael *et al*, 1981).



1. Anteroposterior (sagittal) diameter
2. Transverse diameter
3. Interfacetal diameter
4. Depth of the lateral recess,
5. Interlaminar diameter

Figure 5 : Diagram of the spinal canal. The lateral recess (4) is bounded anteriorly by the posterior part of the vertebral body, posteriorly by the superior articular facet, and laterally by the pedicle.

(Adopted from Neuroradiological evaluation of lateral recess syndrome. Michael A. Mikhael, (1981). Radiology.)

The intervertebral discs are fibrocartilagenous cushion serving as the spine's shocking absorbing system to protect the vertebrae and nerves. Each is composed of an outer annulus fibrosus and a central nucleus pulposus. The strength of the lumbar disc is related to fluid and proteoglycan content of the disc. Proteoglycan (PG) molecules are important because they attract and retain water. Although both annulus fibrosus and nucleus pulposus are composed of water, collagen and proteoglycans (PGs), the amount of fluid (water and PGs) is the greatest in nucleus pulposus. The nucleus pulposus contains a hydrated gel-like matter that resists compressions.

The spine functions best within a realm of static and dynamic stability. Bony architecture and associated specialized soft tissue structures, especially the intervertebral disk, provide static stability. Anterior elements bear over 90% of forces transmitted through the lumbar spine in sitting; during standing, this portion decreases to approximately 80%. Posterior elements of the lumbar spinal functional unit typically bear less weight than anterior elements in all positions.

Dynamic stability, however, is accomplished through a system of muscular and ligamentous supports acting in concert during various functional, occupational, and avocational activities.

The discs allow some vertebral motion, ie extension and flexion. Even though each disc has limited movement, considerable motion is possible when several discs combine forces.

2.3 PATHOPHYSIOLOGY

The incidence of degenerative disc increases with age (Powell *et al,* 1986). Lumbar spinal stenosis is one manifestation of the general process of spinal degeneration that occurs with aging. The distribution of axial load is responsible for the typical localization of spine degeneration. In the lumbosacral region, the most frequently degenerated levels are the lower lumbar level, ie L4/5 and L5/S1, because they are the sites for the highest dynamic and static load. The functional integrity of the spinal curves also contributes to the degenerative changes. Spinal curves allow optimal redistribution of axial load. When curves are preserved, the spine is 30 times more elastic than a straight structure. If correct spine alignment is lost, an asymmetrical load distribution may cause focal or diffuse spine degeneration. As the degenerative process progresses, relative anterior-to-posterior force transmission approaches parity.

In degenerative disc disease, there are changes of the intervertebral discs and structures surrounding it, causing either reduced in disc height, disc bulge or prolapse, osteophytes formation or ligamentous hypertrophy, of which any of this could cause spinal canal stenosis, lateral recess stenosis or intervertebral foramen stenosis (Figure 6). These changes would impinge and compress onto the nerve root causing the symptoms.

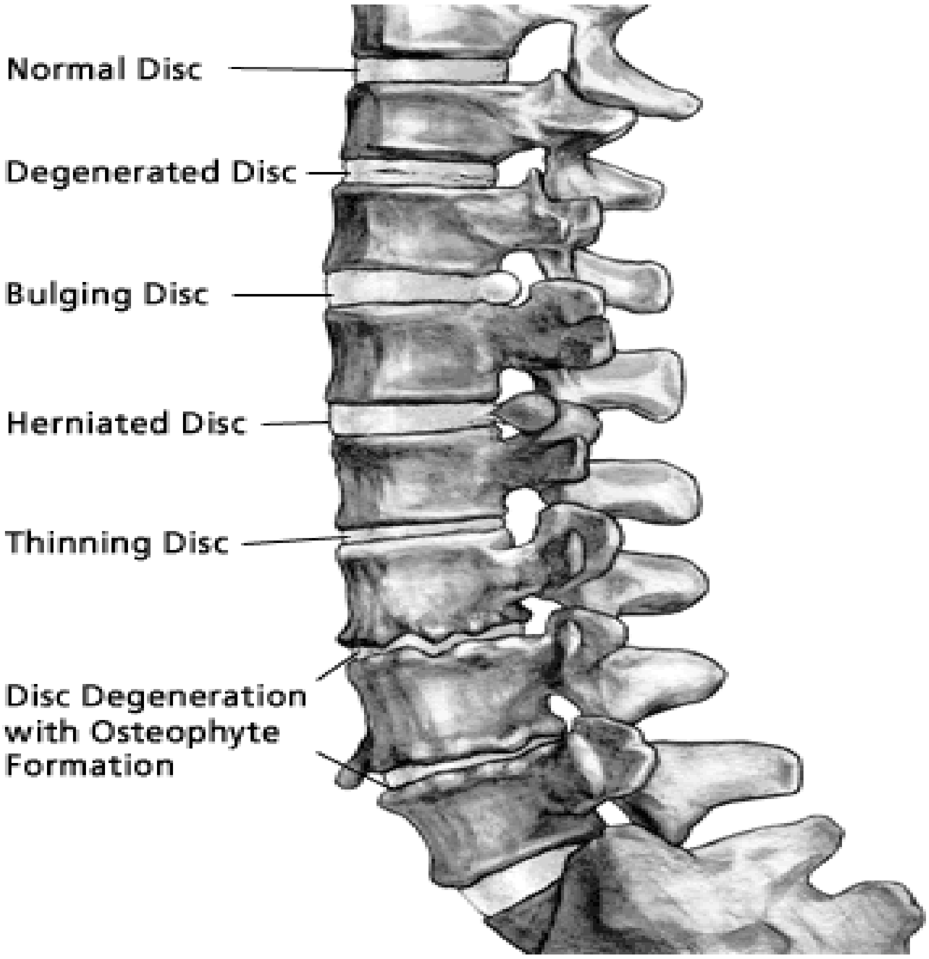


Figure 6: Changes in degenerative discs

Adopted from *Spine Universe,* Stewart G, 2010.

Spinal canal stenosis is a condition in which part or all of the entire spinal canal is stenosed (Kenneth and Hesselink, 1997). It results from progressive narrowing of the central spinal canal and the lateral recesses (Lennard A Nadalo, 2010). The essential content of the spinal canal includes the spinal cord, the cerebrospinal fluid (CSF) of the thecal sac, and the dural membranes that enclose the thecal sac. The spinal canal may become narrowed by bulging or protrusion of the intervertebral disc annulus, herniation of the nucleus pulposus posteriorly, thickening of the posterior longitudinal ligament, hypertrophy of the facet joints, hypertrophy of the ligamentum flavum.

In an article by Michael B Furman *et al*. (2010), the lateral recess stenosis is further compartmentalized into the entrance zone (lateral recess), mid zone, exit zone, and far-out (far lateral) stenosis:-

- **The entrance zone or lateral recess** lies medial to the pedicle and superior articular process (SAP). Consequently, lateral recess stenosis arises from facet joint SAP hypertrophy. Other causes include developmentally short pedicle and facet joint morphology, as well as osteophytosis and herniated nucleus pulposus (HNP) anterior to the nerve root. The lumbar nerve root compressed below SAP retains the same segmental number as the involved vertebral level (eg, L5 nerve root is impinged by L5 SAP).
- **The mid zone (intervertebral foramen)** extends from the medial to the lateral pedicle edge. Mid-zone or intervertebra foramen stenosis arises from osteophytosis under the pars interarticularis and bursal or fibrocartilaginous hypertrophy at a spondylolytic defect.
- **Exit-zone** involves an area surrounding the foramen. This area extends inferiorly till the intervertebral discs level. Exit zone stenosis arises from facet

joint hypertrophy and subluxation, as well as superior disk margin osteophytosis. Such stenosis may impinge the exiting spinal nerve.

- **Far-out or far lateral (extracanalicular) stenosis** entails compression lateral to the exit zone. Such compression occurs with far lateral vertebral body endplate osteophytosis and when the sacral ala and L5 transverse process impinge on the L5 spinal nerve.

The symptoms of lumbar stenosis can either be a neurogenic claudication due to central canal narrowing or radicular symptoms due to narrowing of the intervertebral foramen. Low back pain due to nerve root impingement or compression in the lumbosacral spine can occur at any of the level as the nerve root descends, either within the spinal canal and lateral recess, or exits through the intervertebral foramen. The oblique course of the lateral recess exposes it to narrowing due to thickening of the superior articular facet. As the nerve root approaches the pedicle, the canal forming the lateral recess becomes smaller; thus thickening of the facet is more likely to compress the nerve root at the superior border of the pedicle (Michael A Mikhael *et al*, 1981).

In cases of severe lumbar stenosis, innervation of the urinary bladder and the rectum may be affected, but lumbar stenosis most often results in back pain with lower extremity weakness and numbness along the distribution of nerve roots of the lumbar plexus.

2.4 IMAGING TECHNIQUE

In the evaluation of degenerative spine disease, multiple anatomic sites need to be imaged, including the intervertebral disk, spinal canal, spinal cord, nerve roots, neuroforamina, facet joints, and the soft tissues within and surrounding the spine (Hesselink, 2010). The severity of disc changes, degree of spinal canal and neuroforamina stenosis and their effect on the spinal cord and exiting nerve roots will determine the management of the patients.

Plain radiographs have a limited diagnostic value because degenerative changes are age-related and are equally present in both asymptomatic and symptomatic persons. However, it still serve as an initial and important radiological investigations in patients with degenerative spine. It is quick and easy to perform, inexpensive and noninvasive, and readily available in most clinics. It is able to provide a lot of information on the severity of the disease. It is good in demonstrating alignment of the lumbar vertebrae, osteophytes formation, irregularities of the vertebral end plates and sclerosis of the bones. Another important finding on plain radiographs of patients with degenerative disc disease is decreased in disc height. This is often accompanied by spondylolisthesis of the vertebra and subsequent neuroforamina stenosis.

Following surgical decompression, plain radiographs serve as good and reliable tool in evaluation of bone healing and maturation of surgical fusion.

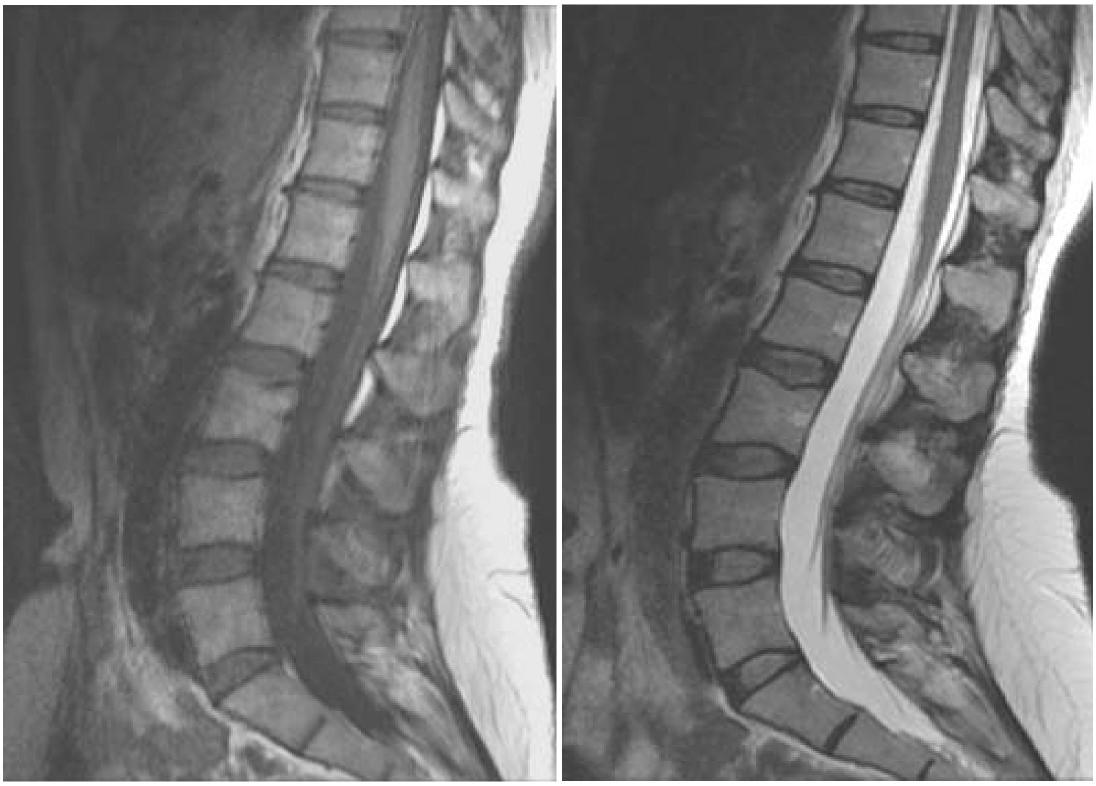
The gold standard modality for visualizing the herniated disc is magnetic resonance imaging (MRI), which has been reported to be as accurate as CT myelography. Many pulse sequences are available, and specific protocols vary among different MR sites. There is general agreement that the spine needs to be imaged in at least two planes, and surface coils are used almost exclusively. Fast spin-echo (FSE) techniques allow enormous time savings, and if available, they have replaced conventional spin-echo for T_2-weighted imaging of the spine.

MRI, being a superior imaging modality to demonstrate soft tissue contrast, is excellent in determining soft tissue causes of stenosis and for determining effect on neural structures. It also has the ability to demonstrate damage to the intervertebral disc, including annular tears and edema in the adjacent end plates. As with CT scans, MRI can reveal bulging and degenerative discs in asymptomatic person. MRI is the technique most frequently and extensively used in the evaluation of foraminal stenosis. It is also used to evaluate nerves exiting from the foramen. However, recent studies have shown that Magnetic resonance myelogram (MRM) is more valuable and reliable in pre-surgical diagnosis of lumbar foraminal stenosis (Song KS, 2008).

A normal MRI lumbosacral will demonstrate normal intervertebral disc which is hypointense on T1WI and hyperintense on T2WI, due to high water content (Figure 7). The disc height is preserved and no bulge seen. The vertebra body shows homogenous signal with preserved height and smooth outline.

Changes is degenerative spine is demonstrated as dessicated disc with reduced height and disc bulges, irregularities of endplates and fatty marrow changes (Figure 8).

MRI changes of disc degeneration should be interpreted with cautions. One third of patients without low back pain have signs of degenerative discs on MRI. In symptomatic patients, MRI findings were not correlated with severity of symptoms. Therefore, abnormalities on MRI must be strictly correlated with age and any clinical signs and symptoms before operative treatment is contemplated (Boden *et al*, 1990)



(a) (b)

Figure 7 : Sagittal MRI of lumbosacral spine of normal lumbar spine

(a): T-1 weighted image (b): T-2 weighted image

In this figure, the normal lumbar lordosis is preserved. The vertebral body height and width preserved. The intervertebral disc height preserved with normal signal intensity on both sequences.

Adopted from *Spine Universe*, Stewart G, 2010.

(c) (d) (e)

Figure 8 : Sagittal T-2 weighted image MRI of degenerative lumbosacral spine

(c): Dessicated disc at L4/L5

(d): Disc protrusion at L5/S1

(e): Multi-level endplate irregularities with reduced disc height and posterior disc bulge

Adopted from *Spine Universe*, Stewart G, 2010.

In patients younger than 50 years old, disc extrusion and sequestration, nerve root compression, endplates abnormalities, and severe osteoarthritis of the facet joints may be predictive of low back pain in symptomatic patients. (Weishaupt *et al*, 1998).

The role of imaging in spinal stenosis is to confirm the clinical diagnosis, identify the level of stenosis, establish causes, and guide treatment. Any surgical decisions should be firmly based on the clinical symptoms and corroborating results of diagnostic testing. The accuracy of MRI for predicting the presence of disk herniations at surgery is relatively high (varying from 76% to 96%), and thus it has become the investigation of choice for patients suspected of lumbar disc herniations (Rijn, 2005).

Post-operatively, Magnetic resonance myelography (MRM) is a non-invasive, efficient and reliable imaging tool in confirming post-operative decompression in lumbar discectomy patient.

In a study done by Pankaj R Patel *et al*, (2010), the MRM specificity and sensitivity was reported as 92% and 33.33% respectively which is better than conventional MRI. In their study on fifty three patients with single level disc herniation underwent discectomy, 47 patients (88.7%) showed positive clinico-radiological correlation.

2.5 MANAGEMENT

While most patients with degenerative disc disease only need conservative and medical management, a small proportion of them may need to undergo surgery. Less than 2% of symptomatic patients undergo operative treatment. Surgical intervention is best directed at those with unremitting nerve root symptoms. The purpose of the surgery is to remove the diseased disc and as such remove the compression of the nerve or spinal cord so as to relieve the pain and restore function to the nerves.

Among the surgical options usually practiced include :

i) Laminectomy - removal of the laminae overlying the spinal canal and of the protruding disc

ii) Micro discectomy - removal of fragments of herniated disc through a smaller incision without doing a laminectomy

iii) Spinal fusion - fusing of vertebrae together with bone grafts or metal rods .

2.6 POSTERIOR LUMBAR INTERBODY FUSION (PLIF)

Previously, lumbar fusions were performed using the intertransverse technique, necessitating wide exposure and possible use of iliac crest graft. Recent technologic advances in cage technology, instrumentation and knowledge on bone biology have widened the scope of fusion options, allowing the surgeon a variety of interbody devices, and surgical methods to assess disc space, provide anterior column support, secure rigid fixation and achieve solid fusion. All these goals can be achieved through the well-known posterior approach (P M Arnold *et al.*, 2009).

Posterior Lumbar Interbody Fusion (PLIF) is one of the surgical techniques that was used to decompress the spinal cord and nerve roots, at the same time fusing the vertebrae together in order to restore the alignment and gain spinal stabilization. The surgical approach was originally advocated by Cloward, later modified by Lin and others, are now well-known to spine surgeons. This technique is now widely practiced in Malaysia as well as in Hospital Raja Perempuan Zainab II.

In this technique, the surgery is done using posterior approach. Skin incision is made at the midline of the back, followed by incision to the muscles at this area. Laminae are then removed (laminectomy) to gain access to the disc space. Once the disc space is cleared, an interbody spacer is placed into the disc space with disc distraction. The spacer remains in disc space and left under compression. The fusion is then strengthened by adding pedicle screw fixation (Figure 9).