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Magnetic Resonance Imaging findings and clinical outcome scores in patients presenting with degenerative lumbar spinal stenosis

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Declaration

I, Leah Dimakatjo Ramushu, do hereby declare that this report is my own work. It is being submitted for the degree Masters in Medicine (Orthopaedics) at the University of Witwatersrand Johannesburg. I have not submitted it for any other degree at another university.

Signed:

Date:

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Prof M Lukhele, Supervisor

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Prof Bischof, Mr Poopedi, Orthopaedic Surgery Department

Spine patients

Dedications

To my late parents Adam and Eva Ramushu

Definitions

Achondroplasia – small stature skeletal dysplasia due to a disorder of chondrocytes.

Cauda equina – bundle of spinal nerves and nerve roots consisting of second to fifth lumbar nerve pairs, first to fifth sacral nerve pairs and coccygeal nerve all of which originate in conus medullaris of the spinal cord.

Cauda equina syndrome – lower motor lesion with damage to cauda equina with variable loss of motor and sensory to the lower limbs and bladder and bowel.

Chemonucleolysis- procedure that involves dissolution inner part of the vertebral disc material by injection of an enzyme.

Hereditary multiple exostoses – autosomal dominant condition with growth of cartilage capped benign bone tumours around areas of active bone growth

Morquio disease – autosomal recessive lysosomal storage disorder caused by deficiency of N-acetylgalactoseamine 6 resulting in accumulation of keratan sulphate causing disproportionate dwarfism, skeletal abnormalities and spine abnormalities among others.

Spinal dysraphism – heterogenous congenital malformations of the spine and spinal cord

Thecal sac – membrane of the dura matter, which surrounds the spinal cord and the cauda equina

Abstract

Study design. This is a prospective correlational study.

Objectives 1. Assessment of radiological parameters of spinal stenosis using Magnetic Resonance imaging. 2. Clinical assessment of patients with Oswestry disability index and Neurogenic claudication outcome score questionnaires. 3. To assess correlation between clinical assessment questionnaires' scores and radiological parameters.

Background. Spinal stenosis is a common presentation in the elderly and a reason for surgical intervention. Diagnostic criteria are still inconclusive. There is poor correlation between clinical and radiological findings. New observations have been described and whether they improve diagnostic criteria remains to be seen.

Methods. 30 patients with spinal stenosis were included in the study. The 2 questionnaires were administered and Magnetic Resonance Imaging copies were obtained. Questionnaires and images were analyzed. Osirix programme was used to analyze the images and do the measurements. Data was entered onto an excel sheet and analyzed using Statistica software. Frequencies and correlations were done.

Results. The age range was between 41 and 85.There were 22 females and 8 males. L4/L5 was the commonest level involved in 23 patients. Multilevel involvement was 23% and those patients had a higher morphological grade, which was statistically insignificant. The commonest morphological grade was C. Sedimentation was positive in 93% of the patients. The Oswestry disability Index and Neurogenic Claudication Outcome score were negatively correlated, which was statistically significant, $p = 0.0004$. There was no correlation between clinical and radiological features.

Conclusion. Spinal stenosis remains a clinical dilemma. There is variability within the population and lack of correlation between clinical and radiologic features. Radiological features however correlate with each other, but do not help with optimizing patient care.

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Chapter 1

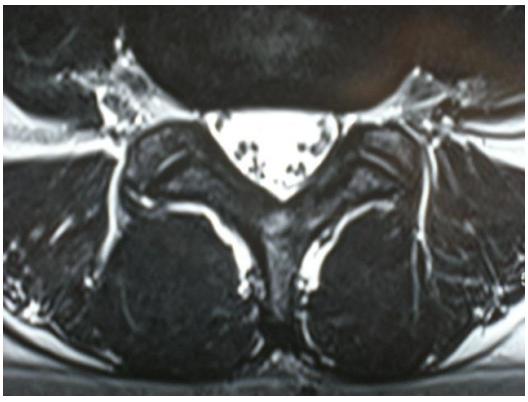
1.0 Introduction

1.1 Background

This study is about lumbar spine nerve roots (cauda equina) organization in the spinal canal. The cauda equina starts at the level between the first and second lumbar vertebra and consists of the nerve roots supplying the lower limb and bladder and bowel. The nerve roots are encased in dura with spinal fluid and exit the canal at each level of the spinal column. The normal anatomy of the nerve roots has been studied by Cohen et al., 1991 and it has been reported that there is an organized pattern of the intrathecal nerve roots in the cauda equina.[1,2]

Visualization of the cauda equina on contrast enhanced Computerized Tomography and Magnetic Resonance Imaging axial cuts revealed a specific pattern of organization of the cauda equina. There was a crescentic oblique pattern of nerve at the lower lumbar levels which was also apparent in the more crowded proximal sections.[1,2] (Appendix 1)

Degeneration of the spine and narrowing of the spinal canal results in changes in the outline of the nerve roots in the spinal canal as shown in figure 1 and 2.



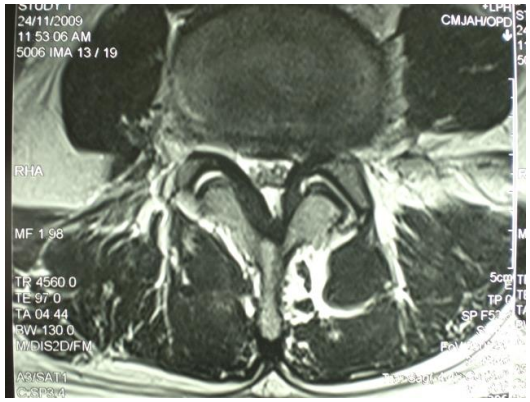


Figure 1a. Normal **Figure 1b. Spinal stenosis**

(Taken from Charlotte Maxeke Hospital patients)

Degenerative lumbar spinal stenosis is a commonly diagnosed condition in the elderly population. The prevalence of lumbar spinal stenosis is reported to increase with age. It is often a common cause of back and leg pain. Natural history of spinal stenosis varies. Etiology and pathogenesis of the anatomic features as well as the clinical features of lumbar stenosis are heterogeneous.[3,4,5,6]

1.2 Definition of spinal stenosis

Lumbar spinal stenosis is any type of narrowing of the spinal canal, nerve roots or intervertebral foramina as defined by Verbiest in 1980. The stenosis can be local, segmental or generalized, congenital or acquired and might be caused by bone or soft tissue. It describes a constellation of symptoms that includes leg pain, difficulty with ambulation and neurological deficit. It can be classified as primary or secondary. It is a common cause of low backache and may present at any age and the most common form is the degenerative type.[3,4,5,6]

1.3 Incidence of spinal stenosis

Incidence of lumbar spinal stenosis is not fully known. Verbiest, 1980 found a ratio of 1 operated patient with spinal stenosis to12 operated patients with disc herniation.[3] Boden et al, 1990 found lumbar spinal stenosis in 1% of people under 60 years and 21% of individuals older than 60 years.[4] The authors advised that abnormalities on Magnetic Resonance Imaging must be correlated with age and clinical signs before any surgical intervention to address the spinal stenosis can be undertaken.[3]

1.4 Causes of spinal stenosis[5,6]

1.4.1 Primary stenosis

Failure of spinal canal to grow normally including the following:

1.4.1.1 Congenital

There is a defect in the spine bony elements and the spinal canal dimensions remain narrow. Causes include spinal dysraphism and failure of vertebral segmentation.

1.4.1.2 Developmental

Conditions which include inborn errors of bone growth, Achondroplasia, Morquio disease, Hereditary multiple exostoses and idiopathic conditions with bony hypertrophy of the vertebral arch. The spine growth plates close prematurely and the spine bony elements are thus short and thickened and the spinal canal becomes narrow.

1.4.2 Secondary stenosis

Normal vertebral canal dimensions at skeletal maturity including the following:

- Degenerative spinal stenosis
- Spondylolisthesis
- Post fusion from the level of fusion
- Post discectomy
- Post laminectomy
- Post fracture

1.4.2.1 Degenerative spinal stenosis

It is the most common type of spinal stenosis. Degeneration most often begins in the disc. The nucleus pulposus loses water and its ability to distribute stresses decreases and this leads to tears in the annulus fibrosus. Facet joint arthritis can precede disc degeneration or the loss of height of the disc degeneration result in abnormal biomechanical stresses on the facet joint and thus arthritis. Abnormal biomechanical stresses, the ligamentum flavum hypertrophy, facets hypertrophy and together with osteophytes, lead to canal narrowing.[3,4,6,7]

The loss of disc height results in redundancy of the ligamentum flavum. When patients extend the back, the interlaminar space is reduced and this results in buckling of ligamentum flavum into the canal and with associated degeneration of the ligamentum and formation of cysts in the ligamentum flavum and calcifications, the canal diameter is further narrowed. Facet degeneration can also lead to formation of synovial cysts which can lead to canal and recess stenosis. [2,3,4,7,8]

1.4.2.2 Spondylolisthesis

Spondylolisthesis is the forward slip of the superior vertebra in relation to the inferior vertebra. Isthmic or degenerative spondylolisthesis can cause spinal stenosis. The degenerative spondylolisthesis causes < 50% slippage of the vertebra from facet joint and capsule attenuation. Central stenosis is less common due to the slippage remaining less than 50%. The facet facet arthrosis and slippage causes foraminal stenosis. Isthmic spondylolisthesis results from elongation or attenuation of the pars interarticularis. Fibrous repair of the pars defect worsen the stenosis as well as bony spurs formation.

1.4.2.3 Post-fusion from level of the fusion

Spinal fusion is a commonly performed procedure in spine. Bony overgrowth of fusion mass can result in spinal canal encroachment. Stenosis can also occur above or below the fusion level due to additional stress above and below fusion resulting in degenerative spinal stenosis.

1.4.2.4 Post-discectomy

Discectomy is a surgical procedure perfomed as an option for the management of disc herniation. Surgical failure to decompress lateral recess in patients over 40 years during discectomy can result in patients having lateral recess stenosis. Spinal stenosis can also result post-chemonucleolysis due to significant motion segment collapse.

1.4.2.5 Post-laminectomy

Laminectomy, which involves removal of lamina surgically to decompress the spinal canal, can heal with significant scarring around dura can gradually constrict the nerve roots/theca and cause spinal stenosis.

1.4.2.6 Post-fracture

Fractures of the spine can cause spinal stenosis by either bony fragments intrusion into the canal, segmental instability at the fracture site or late degenerative changes after the fracture has healed.

1.5 Anatomical classification of spinal stenosis

Classification based on anatomical region of narrowing (figure 2):

- Central
- Lateral recess
- Foraminal
- Extraforaminal[6]

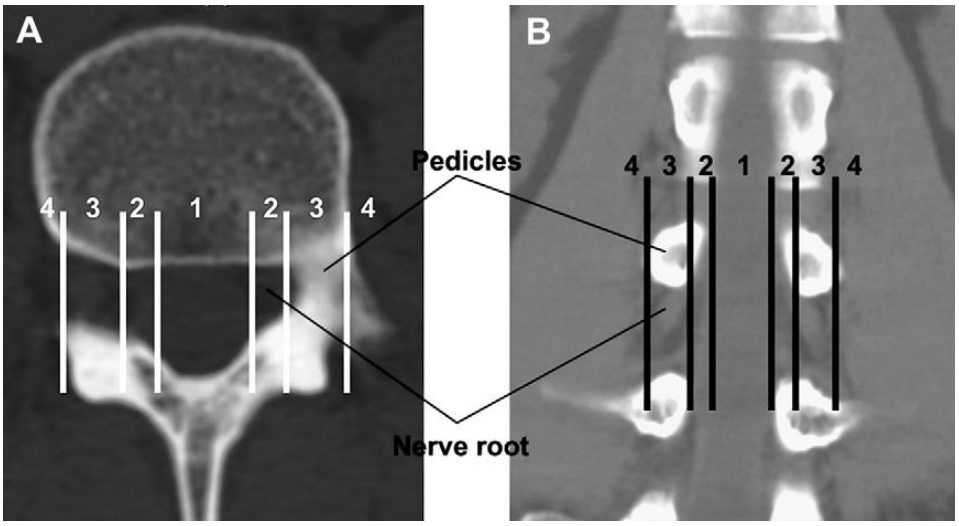


Figure 2: Coronal and axial views of lumbar vertebrae showing areas of spinal stenosis: 1- Central, 2- Lateral recess, 3- Foraminal, 4- Extraforaminal (Picture taken from Genevay et al[6])

1.5 Clinical presentation of spinal stenosis

The concept of neural tissue mobility as described by Weisz et al 1983, emphasizes that lack of adequate intracanal space leads to symptomatic stenosis.[12] It is known that in normal subjects, the spinal canal allows free movement of the nerve roots. In contrast, subjects with degenerative spinal stenosis have constriction and restriction of nerve roots in the spinal canal as a result of the spinal canal narrowing.[3,4,5,12]

Clinical presentation varies and intensity of symptoms fluctuates (table 1). Patients can present with back pain, leg pain, sensory disturbances, bladder problems and weakness of the legs. Patients' symptoms are made worse by prolonged standing, any form of activity and walking. The leg symptoms can be fatigue, heaviness, weakness or paraesthesia and it encompasses buttock, thigh, posterior leg and feet. Sitting or lying with hips or spine flexed relieves symptoms either substantially or completely. Back extension worsens symptoms.[4,5]

Walking distance diminishes and can be increased by flexing the back. Pushing a shopping cart or walking uphill results in flexion of the back, which increases walking distance. Patients end up adopting a posture of flexed hips and knees. They can also present with nocturnal leg cramps and neurogenic bladder. [3,4,5,8]

Table 1: Main symptoms in 100 patients with Lumbar Spinal Stenosis and sciatica (Amundsen et al 1995)[4]

Symptoms	**Number of patients (%)**
Lumbar back pain	95
Sensory disturbance in the legs	70
Weakness in legs	33
Voiding disturbance	12
Claudication	91
Relief of pain by bending forwards	61
Worsening on walking downhill	40

Neurogenic claudication should be differentiated from vascular claudication. A patient with vascular claudication has weak or absent pulses, symptomatic walking distance is constant, walking up the stairs brings about symptoms and exercise on a stationary bicycle is not tolerated. [5,6]

Objective findings include nonspecific reduced mobility of the back with extension more limited than flexion (table 2).[4] There can also be associated hamstring tightness. Neurological examination is usually normal or there is mild motor weakness or sensory changes. Straight leg raising test is usually negative in patients with spinal stenosis. [4,5,6]

Table 2: Main objective findings in 100 patients with lumbar spinal stenosis (Amundsen et al 1995).[4]

Findings	Number of patients (%)
Scoliosis	56
Sensory dysfunction	51
Reduced reflexes	47
Lumbar tenderness	40
Reduced spinal mobility	36
Lasegue's test positive	24
Paresis in the legs	23
Perianal numbness	6

1.6 Imaging modalities

The role of imaging in spinal stenosis is to confirm spinal stenosis, identify the site and assist with preoperative planning. Interpretation of radiologic findings for spinal stenosis may be difficult owing to heterogeneity of clinical symptoms. [13,14,15]

Modalities available include x-rays, myelography, computed tomography and Magnetic Resonance Imaging.

1.6.1 X-rays

X-ray is a simple imaging modality which also allow for dynamic imaging of the spine, assessment of instability and can be used intraoperatively for confirmation of site of surgery.[13,14] Deformity of the spine and other causes of back pain including osteoporotic fractures and tumour infiltration can be evaluated using X-rays.[13,14]

1.6.2 Myelography

Myelography is invasive as it involves introduction of radiopaque dye into the spinal canal. Myelography alone allows ability to assess multiple levels of spinal stenosis

without increasing radiation. It can be done in an upright position as well. Myelography alone or in combination with computed tomography has been the mainstay investigation for spinal stenosis for years. Central and lateral spinal stenosis can be defined. The other problem is imaging beyond a complete block as the dye does not pass through. [13,14]

1.6.3 Computed Tomography

The introduction of computed tomography allowed for quantification of spinal stenosis and lateral recess stenosis however the disadvantage is that it exposes patients to higher doses of radiation. It allows for axial viewing of the spine. It has however limitations in ability to assess soft tissues. Intrathecal nerve root cannot be assessed as well because nerve roots look like cerebrospinal fluid on computed tomography. Computed Tomography in isolation without myelography is not advisable for routine assessment of lumbar spinal stenosis. [13,14,16,17]

Computed Tomography Myelography is still an option in patients with contraindications to Magnetic Resonance Imaging. Specificity remains relatively lower due to abnormal findings in asymptomatic patients and the extent of narrowing may be dynamic.[5,13,17]

1.7.4 Magnetic Resonance Imaging

Magnetic Resonance Imaging is now the imaging modality of choice currently with higher sensitivity than Myelography or computerized Tomography or combination of both. It can also show the nerve root in the intervertebral foramen and differentiate between cerebrospinal fluid and intrathecal nerve roots. It does not use radiation and is non-invasive as it uses magnet. [14,15,16,17]

Lurie et al., 2008, reviewed Magnetic Resonance images of 58 randomly selected patients and found interobserver reliability to be higher than intraobserver reliability with a kappa value of 0.73.[18] Prognostic significance could not be determined.[18] Earlier authors,

Speciale et al., 2002, found lower interobserver reliability with kappa value of 0.4 and attributed their findings to lack of defining terms of stenosis.[19]

1.7.4.1 Dural sac cross sectional area

Spinal stenosis remains a clinicoradiological diagnosis. Narrowing of spinal canal is part of the pathology of spinal stenosis and Magnetic Resonance Imaging is the key noninvasive test for lumbar spinal stenosis. Spinal stenosis has been defined as dural cross sectional area of less than 100mm^2 and anteroposterior diameter of less than 10mm as depicted by figure 3 and 4 respectively.[1,2,13,14,20,21]

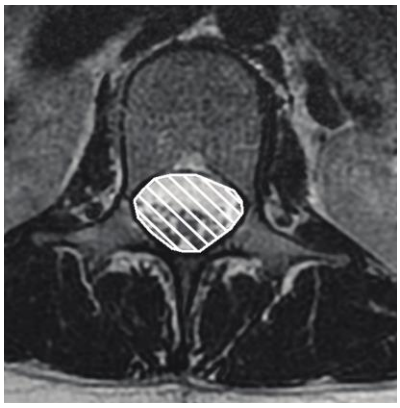


Figure 3: Dural sac cross sectional area (Picture taken from Steurer et al[20])

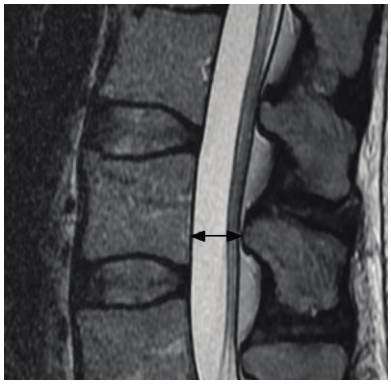


Figure 4: Anteroposterior diameter (Picture taken from Steurer et al[20])

There are however multiple definitions of the values, and the concept of spinal reserve capacity has been postulated as well.[12] The degree of radiological narrowing spinal canal narrowing that leads to clinically significant stenosis is not clear.[11,12] Owing to asymptomatic patients with radiological stenosis the question has always been what is the critical dural sac cross sectional area, hence some authors have suggested an area of 70mm^2 as the critical dural sac cross sectional area.[4,12,20,21]

Dural cross sectional area has good interobserver and intraobserver variability. It is however affected by the slice orientation when taking magnetic resonance imaging scans. Measurements of dural cross sectional area have been shown to be valid for angulations less than 15 degrees because with increasing obliquity of the scans so does 13% of the dural cross sectional area.[22]

Hamanishi et al., 1994, described a technique to calculate the cross sectional area of the dural tube on transverse cuts of Magnetic Resonance Imaging.[23] (Appendix 2) It was calculated using the product of the anteroposterior and transverse diameter of the dural sac multiplied by a ratio depending on its form. The calculations were done manually and using a digitizer and the results were similar. They found that the dural tube cross sectional areas at L2/3, L3/4 and L4/5 intervertebral levels of patients with back pain were narrower than those without back pain.[23]

This dural cross sectional area has been accepted as a good discriminator of lumbar spinal stenosis, however, it under diagnoses patients with foraminal stenosis, dynamic stenosis and rapidly progressive stenosis. Older patients can be over diagnosed if they have milder symptoms with very low cross sectional area.[24] The other problem is that it is affected by image acquisition techniques including slice orientation. Henderson et al., 2012, has shown that 13% of dural cross sectional area measurements were found to slightly decrease as the angle of the slice increased.[22]

1.7.4.2 Grading of spinal stenosis

A qualitative grading of severity of lumbar spinal stenosis was described based on the morphology of the dural sac on T2 transverse cuts. The cerebrospinal fluid/rootlet content was taken into account. Measurements were taken at a level above or below disregarding proximity to area of maximal stenosis. It only takes cerebrospinal fluid into account and no measurements need to be made and this makes it practical for everyday use. It is independent of vertebral level and image acquisition techniques. It however needs to be validated.[24,25]

Types of Morphological Grading:
A: There is clearly cerebrospinal fluid visible inside the dural sac but its distribution is inhomogeneous.
A1: The rootlets lie dorsally and occupy less than half of the dural sac area.
A2: The rootlets lie dorsally, in contact with the dura but in a horseshoe configuration.
A3: The rootlets lie dorsally and occupy more than half the dural sac area.
A4: The rootlets lie centrally and occupy the majority of the dural sac area.
B: The rootlets occupy the whole dural sac but they can still be individualized, some cerebrospinal fluid is still present, giving a grainy appearance to the sac.
C: No rootlets can be recognized, the dural sac demonstrates a homogenous grey signal with no cerebrospinal fluid signal visible and there is epidural fat posteriorly.
D- No rootlets can be recognized, no epidural fat posteriorly
(appendix 3)[25]

This morphological grading has been found to have prognostic value with grades A and B less likely to need surgery and grade C and D more likely to require surgery. It is not affected by slice orientation during and thus more reliable means of assessing severity of spinal stenosis.[22,24,25]

1.7.4.3 Sedimentation sign

Magnetic Resonance imaging of the spine with the patient in supine position has been shown to result in the nerve roots settling to the bottom part of the dural sac as a result of gravity. When canal narrows, the nerve roots fail to settle at the bottom part of the dural sac. It was named sedimentation sign and is depicted in figure 5 and 6. Absence of this sign was termed positive sedimentation sign. The sign is assessed at a level above or below the level of stenosis because at the level of stenosis the nerve roots are tightly packed due to restriction of cauda equina movements with spinal stenosis.[26,27]

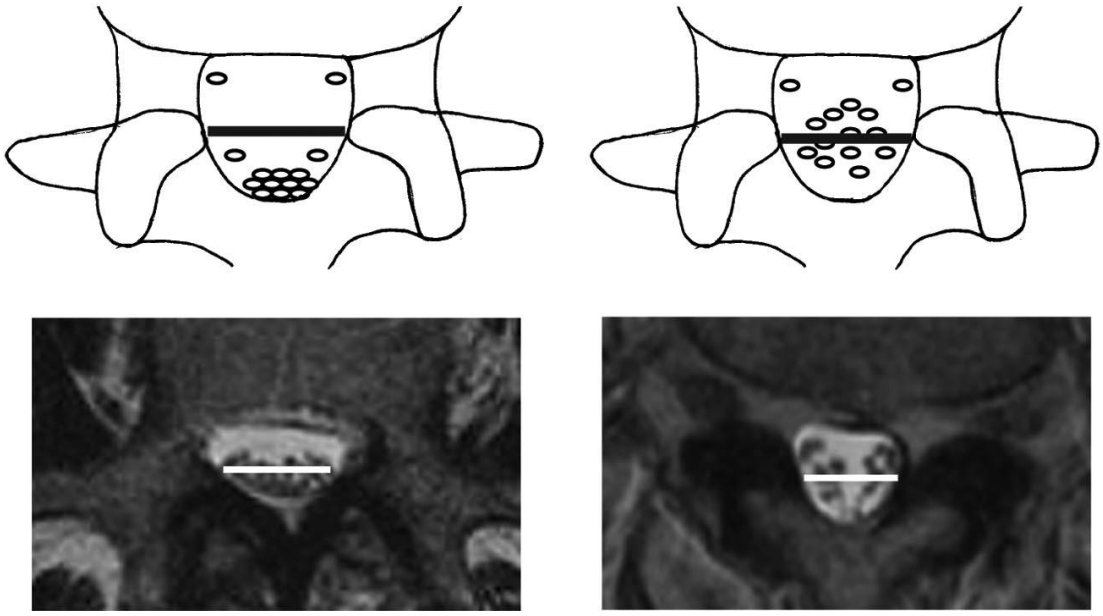


Figure 5a. Negative Sedimentation (Taken from Barz et al[26])

Figure 5b. Positive Sedimentation sign sign (Taken from Barz et al[26])

It has been shown to discriminate well between lumbar spinal stenosis and other pathologies. The sedimentation sign has been found to be patient and clinician convenient in that it is quick to assess and there are no measurements to be made.[26]

Barz et al., 2010, have described this new radiological sign for lumbar spinal stenosis. It was based on the fact that radiological findings don't always correlate with clinical

symptoms, which necessitated development of more ways to diagnose spinal stenosis. Indications for surgery are also not yet clearly defined.[26,27]

1.7 Patient administered questionnaires

1.8.1 Oswestry Disability Index (appendix 4, page v)

Oswestry Disability Index has been considered the gold standard of low back functional outcome tools.[28] Fairbank et al., 2000, reviewed the various versions of the Oswestry Disability index including the initial version from 1976 by John O'Brien.[28] Validation was also reviewed with comparison to other scoring systems.[28] Oswestry Disability Index has been shown to be a better predictor of return to work Version 2.0 was preferred as it specifically asked about the present.[28]

The index assesses everyday functional disability including personal care, mobility, social life, etc. The scoring is as depicted in the table below:

Table 3: Grading of Oswestry Disability Index

Grading	Functionality	Percentage
1	Mild functional disability	0% - 20%
2	Moderate	21% - 40%
3	Severe	41% - 60%
4	Crippled patient	61% - 80%
5	Bedridden	81% - 100%

It has been found to be a better predictor of return to work as it predicts isokinetic performance, isometric endurance and pain with sitting and standing.[28]

1.8.2 Neurogenic claudication outcome score (appendix 5, page viii)

Weiner et al., 1999 developed neurogenic claudication outcome score, which measures outcome functionality in patients with neurogenic claudication and it has been validated for use.[29,31] It is based on the Low Back Pain outcome score by Greenough et al., 1992.[30,31]The last question in the questionnaire is the visual pain score.[29,30] A score of 100 means the patient is asymptomatic and fully functional. Patients who score higher are more functional, in contrast to Oswestry Disability Index.[29,30]

Chapter 2

2.0 Research aim and objectives

2.1 Motivation for study

Accurate diagnosis is a prerequisite to optimal treatment. There are no diagnostic guidelines for spinal stenosis available currently. Management is thus individualized. Studies have failed to show correlation between clinical symptoms and qualitative and quantitative radiological findings. There is also paucity of data from Africa and other developing countries pertaining to spinal stenosis and its clinical and radiological correlation.

2.2 Aim

To review the Magnetic Resonance Imaging axial cuts of patients with spinal stenosis and correlate them clinically with functional outcome questionnaires.

2.3 Primary objectives:

- Assessment of radiological parameters of spinal stenosis using Magnetic Resonance imaging.
- Clinical assessment of patients with Oswestry disability index and Neurogenic claudication outcome score questionnaires.

2.4 Secondary objectives:

To assess correlation between clinical assessment questionnaires' scores and radiological parameters.

2.5 Ethics

Ethics approval was granted, M10218 (appendix 6, page x)

Informed consent was obtained from all patients.

Chapter 3

3.0 Methodology

3.1 Study design

This study was a prospective descriptive study to review clinical presentation and magnetic resonance imaging films of axial cuts of patients with spinal stenosis.

3.2 Study population

Patients with spinal stenosis seen at the spine clinics of Charlotte Maxeke Johannesburg Academic Hospital and Donald Gordon Medical Centre between 01/03/2010 to 31/09/2012.

3.3 Inclusion criteria

- Adults above 18years
- Degenerative spinal stenosis (lumbar back pain, claudication, sensory and motor weakness in the legs, voiding disturbance, relief by bending forwards, worsening on walking downhill, radiological features of degeneration of lumbar spine with dural cross sectional area less than $100mm^2$)

3.4 Exclusion criteria

Non-degenerative spinal stenosis including congenital spinal stenosis, spinal stenosis caused by tumour, trauma or infection.

3.5 Administration of Questionnaire

All patients were given The Oswestry Disability Questionnaire and Neurogenic Claudication Outcome Score to complete. The researcher was present to clarify any questions. The questionnaires were scored as per authors guidelines and results entered into an excel spreadsheet.

3.6 Magnetic Resonance Imaging assessment

Magnetic Resonance Imging is done as part of investigations for patients with clinical stenosis. Magnetic Resonance Imaging was done supine using 1.5 Tesla at 4mm slice thickness. Osirix programme, Swiss Dicom viewer developed in 2003, was used to analyze the images.

The following assessments were done:

- Level of stenosis in the lumbar spine with a cross sectional area less than 100mm^2 and number of levels of stenosis.[20]
- Measurement of anteroposterior and interfacet distance at stenotic level at disc level on T2 sagittal.[20]
- Measurement of dural sac cross sectional morphology of stenotic level at the disc level on T2 axial cuts using the method described by Hamanishi et al., 1994.[23]
- Assessment of sedimentation of nerve roots according to Barz et al., 2010.[26]
- Morphological grading of stenosis as described by Schizas et al., 2010.[25]

3.7 Statistical analysis

The results were analyzed using the Statistica software package version 6 (StatSoft, Tusla, OK, USA). The means and standard deviations of various parameters were analysed. P values of < 0.05 were regarded as statistically significant. Correlations of various clinical and radiological parameters were made. The r value of around zero indicates no linear relationship and its range is from -1 to +1.

Chapter 4

4.0 Results

4.1 Demographics

Thirty patients were recruited, 22 females and 8 males. The youngest patient was 43 years old and the oldest 85 years with a mean of 63.9±10.3 (figure 6). The racial profile of the study population included 15 Caucasian, 11 black and 4 Indian.

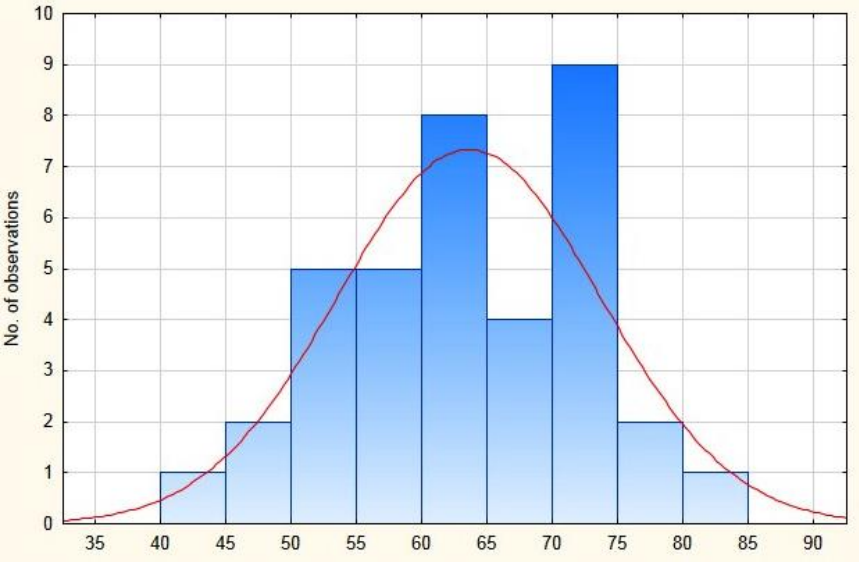


Figure 6: Distribution of age of study subjects

More than half (53%) of the patients were pensioners, 40% employed and 7% unemployed. The high percentage of pensioners can be explained by the advanced age of presentation of degenerative lumbar spinal stenosis in the study population.

4.2 Patient Administered Questionnaires and Walking Distance

With regards to Oswestry Disability Index, 7% had mild disability, 3% moderate, 43% severe, 36% crippled and 10% were bedridden (figure 7). The mean was 58.3 ± 17.4.

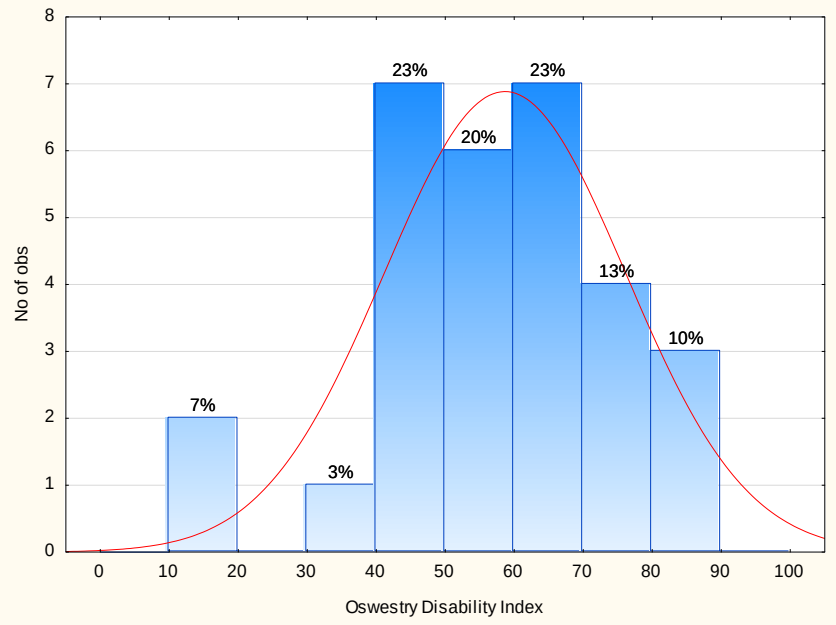


Figure 7: Distribution of Oswestry Disability Index Results

There were 5 patients who did not answer the sex question in both the Oswestry Disability Index and the Neurogenic Claudication Outcome Score. The authors have made allowance for unanswered questions in the scoring system and it was applied in the scoring of the questionnaires.

The mean for Neurogenic Claudication Outcome Score was 22.2 ± 12.4 (figure 8).

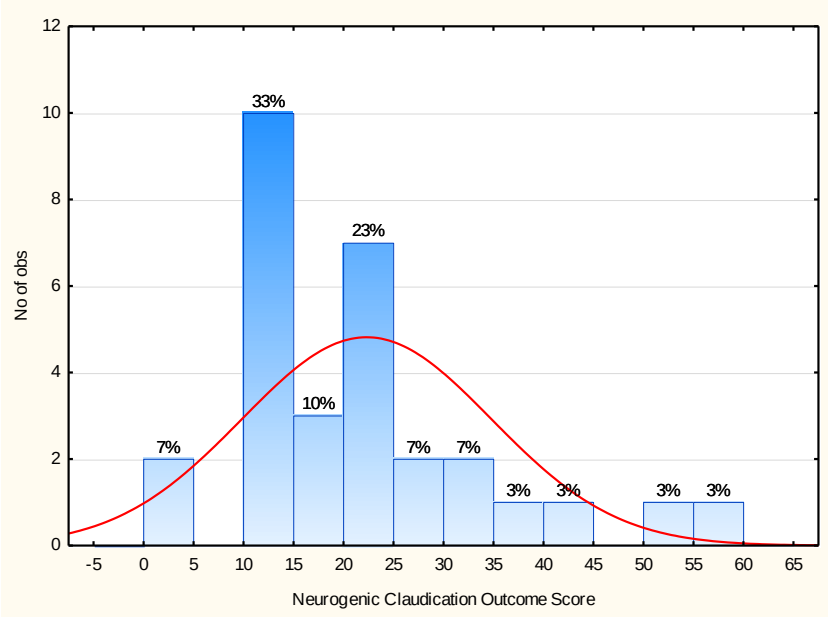


Figure 8: Distribution of Neurogenic Claudication Outcome Scores

Walking distance was taken from the questionnaires and separately assessed. (figure 9). 2 of the 4 patients with walking distance >500m had severe reduction in dural sac cross sectional area as calculated by the Hamanishi technique of 0.54 and 0.6 respectively.

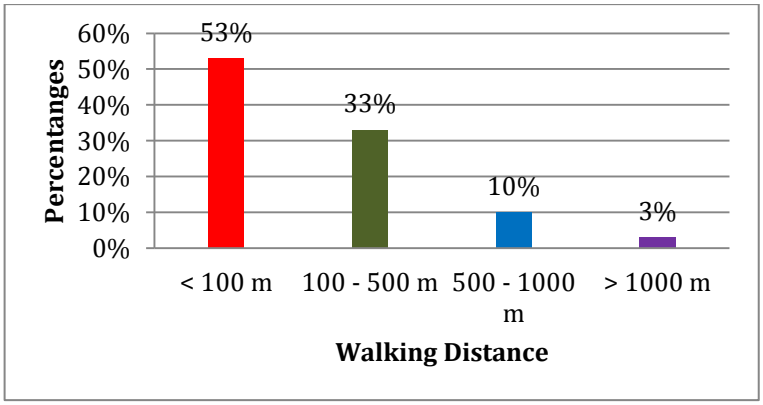


Figure 9: Distribution of walking distance

4.3 Radiological findings

4.3.1 Level of stenosis and number of levels of stenosis

4.3.2 Anteroposterior and interfacet distance

4.3.3 Hamanishi cross sectional area

4.3.4 Sedimentation of nerve roots

4.3.5 Morphological grading

4.3.1 Level of stenosis and number of Levels of stenosis

The commonest level of stenosis (dural cross sectional area less than 100mm^2) was L4L5 with 63%(figure 10). The 2 patients with L2L3 involvement were older than 65 years old.

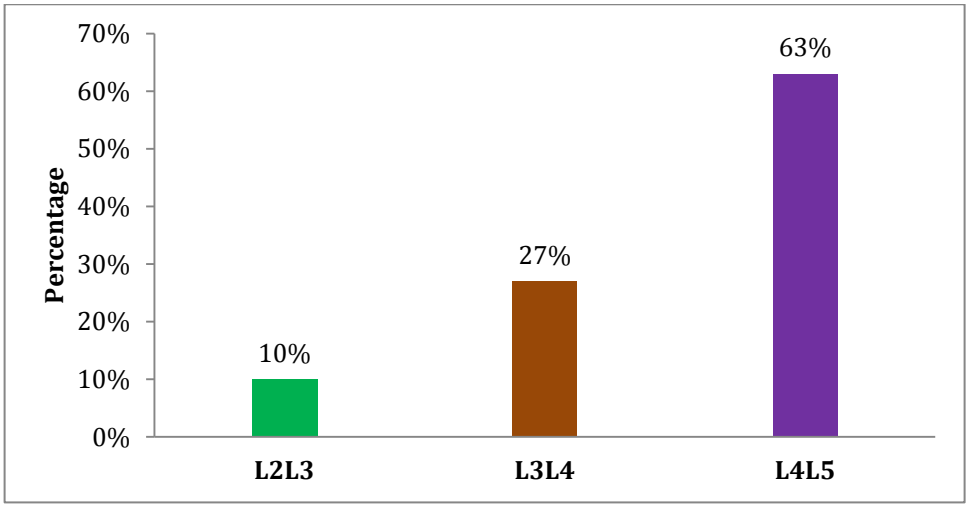


Figure 10: Distribution of level of stenosis

There were 6 patients with double level stenosis and 1 patient with 3 level stenosis making it a 23% prevalence of multilevel stenosis of which 3 were males and 4 females (figure 11). In the patients with multilevel spinal stenosis, the level with the greatest stenosis looking at the cross sectional area was selected for the correlation, with the L4/L5 level the most severely stenosed.

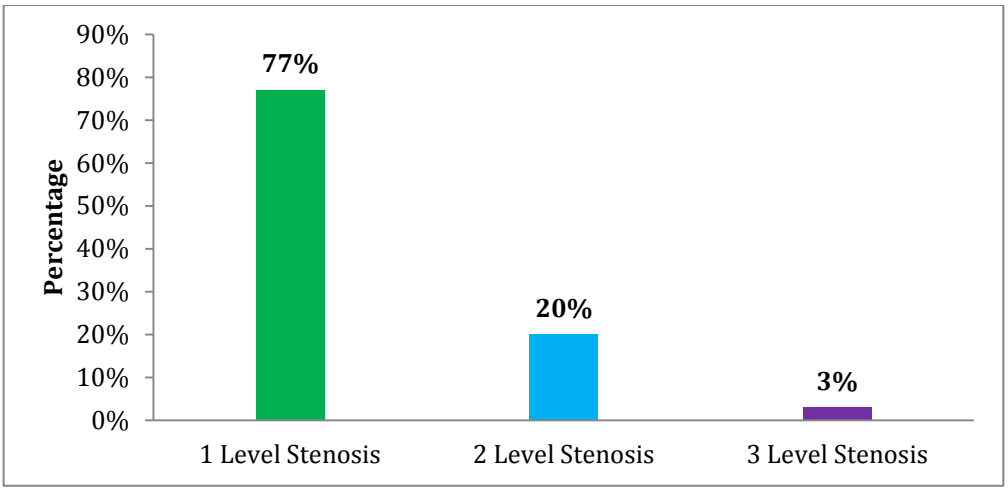


Figure 11: Distribution of number of levels of stenosis

4.3.2 Anteroposterior diameter and interfacet distance

The interfacet distance values were much smaller than the anteroposterior distance values. Their distribution is similar as reflected by the standard deviation (table 3).

Table 4: Summary of anteroposterior diameter and interfacet distance

Variables	Observations	Mean± SD	Minimum	Maximum
Anteroposterior distance	30	1.15cm±0.3	0.6	1.8
Interfacet distance	30	0.8cm±0.2	0.3	1.3

4.3.3 Hamanishi dural cross sectional area

The commonest spinal canal morphology was the 0.6 as described by Hamanishi, which was 67% of the study population (figure 12)

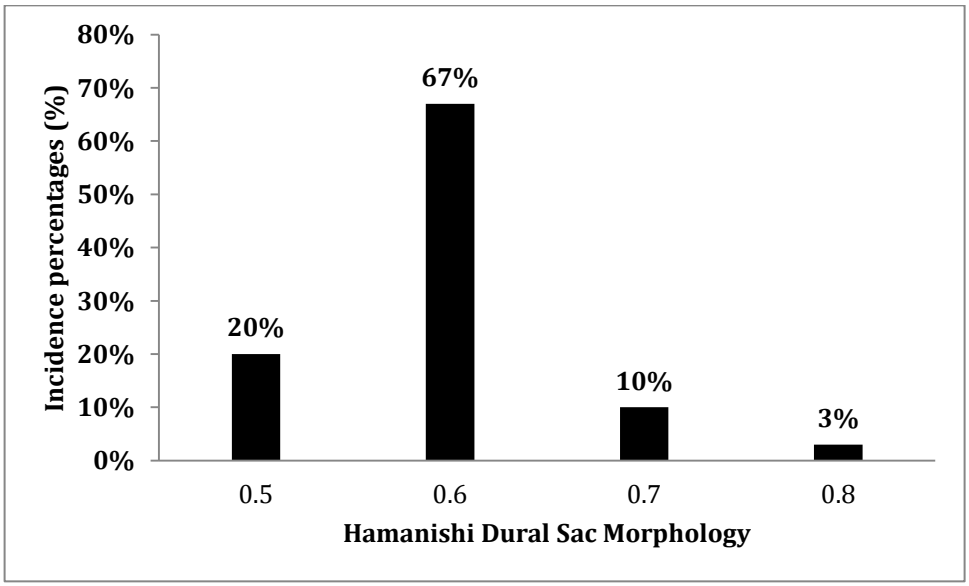


Figure 12: Distribution of dural sac cros sectional area by Hamanishi

4.3.4 Sedimentation sign

Sedimentation sign was negative in 2 patients (7%) and the two cases had dural cross sectional area more or equal to 100mm^2 and dural sac morphology as described by Hamanishi 0.7 and 0.8. The two patients who had negative sedimentation sign were both having stenosis at L4L5 levels. There were however 2 patients with dural sac cross sectional area more or equal to 100mm^2 with a positive sedimentation sign.

4.3.5 Morphological grading

The commonest morphological grade was type C, 13 patients out of 30, 43%.

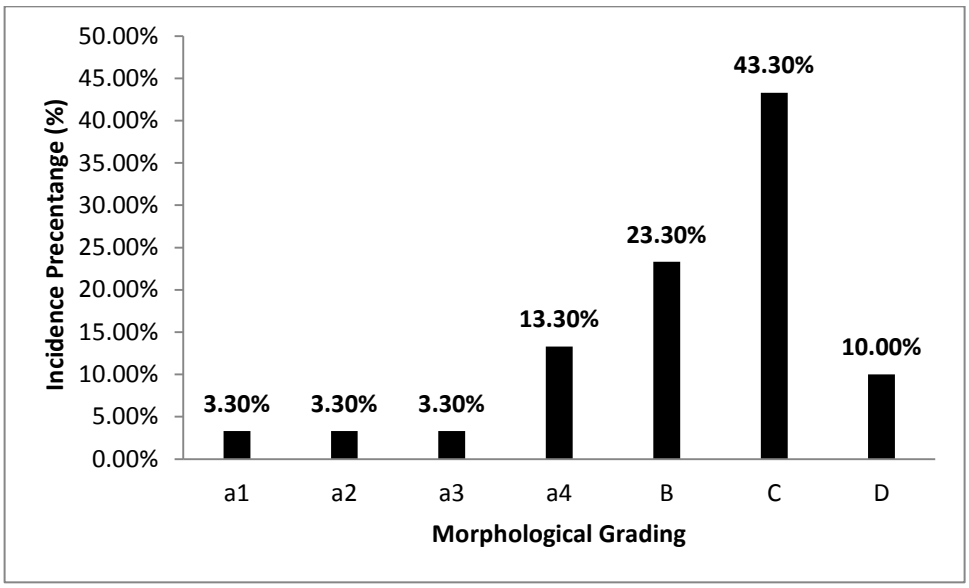


Figure 13: Distribution of morphological grading

4.4 Correlations

4.4.1 Demographics and radiological findings

4.4.2 Demographics and patient administered questionnaire

4.4.3 Radiological findings and patient administered questionnaires

4.4.3.1 Walking distance and dural cross sectional area

4.4.3.2 Walking distance and number of levels of stenosi s

4.4.3.3 Oswestry Disability Index and Morphological grading

4.4.4 Radiological findings

4.4.1 Demographics and radiological findings

There was negative linear correlation between age and morphological grading with an r value of -0.5, which was significant: p = 0.01. The correlation between age and level of stenosis was insignificant with a p value of 0.6.

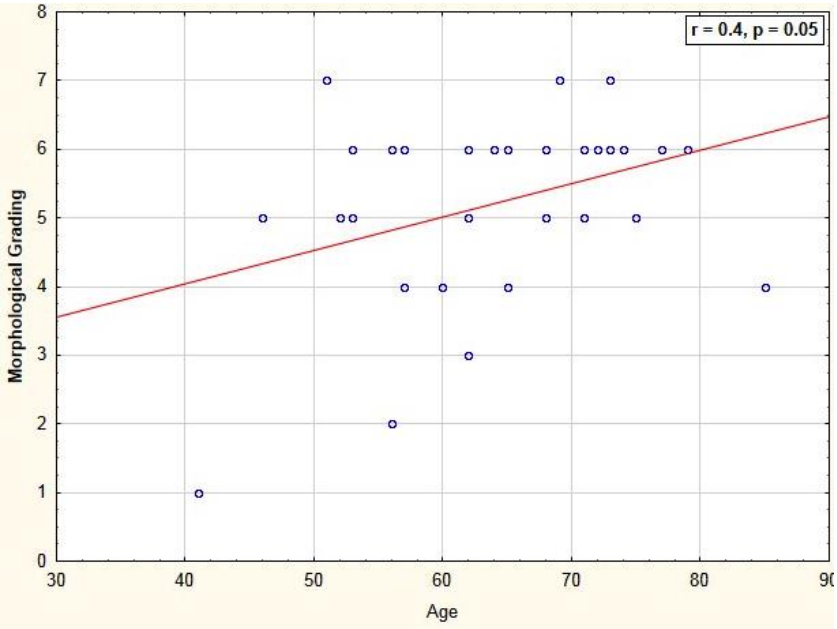


Figure 14: Morphological grading versus age

4.4.2 Demographics and patient administered questionnaires

There is increasing Oswestry Disability Index with increasing age but the correlation is not significant with a p value of 0.3.

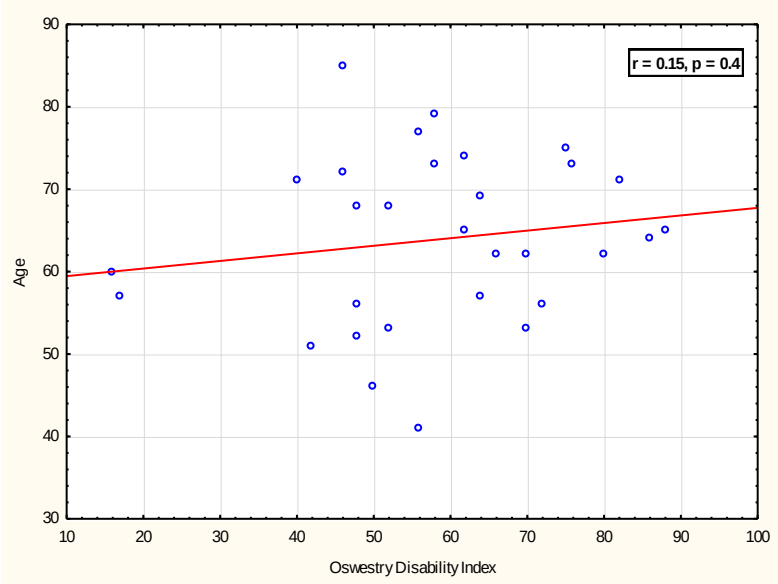


Figure 15: The relationship of Oswestry Disability Index versus Age

4.4.3 Radiological findings and patient administered questionnaires

4.5.3.1 Walking distance and dural cross sectional area

There was no correlation between walking distance and dural cross sectional area. The correlation between walking distance and morphological area was not significant with p value of 0.9 (data not shown).

4.5.3.2 Walking distance and number of levels of stenosis

There was no correlation found between number of levels of stenosis and walking distance, p-value = 0.8.The patient with 3 levels stenosis had a walking distance of <100m (data not shown).

4.4.3.3. Oswestry Disability Index and Morphological grading

There was no correlation between patients' functionality according to the Oswestry Disability Score and severity of spinal stenosis determined by dural sac morphological grading, p value = 0.6. (figure 13).

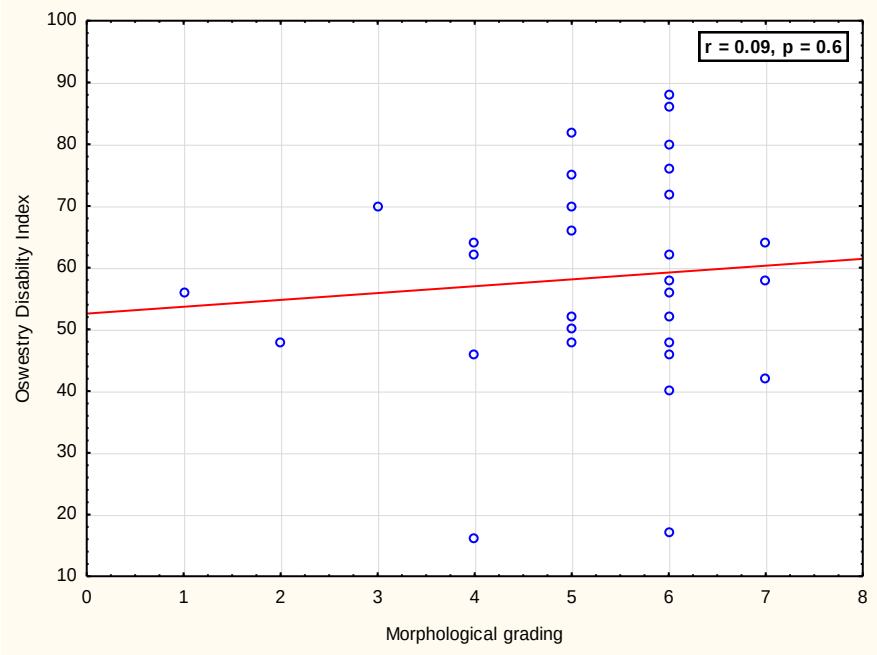


Figure 16: Oswestry Disability Index versus Morphological grading

4.4.4 Radiological findings

4.5.4.1 Interfacet distance and anteroposterior diameter

4.5.4.2 No of levels of stenosis and Morphological grading

4.5.4.3 Morphological grading and Hamanishi cross sectional area

4.5.4.1 Interfacet distance and anteroposterior diameter

The interfacet distance correlated positively with the anteroposterior diameter with a p value of 0.001(data not shown).

4.4.4.2 No of levels of stenosis and Morphological grading

Patients with more than one level involvement tend to have a more severe morphological grade. The relationship was however insignificant: p = 0.17 (figure 17).

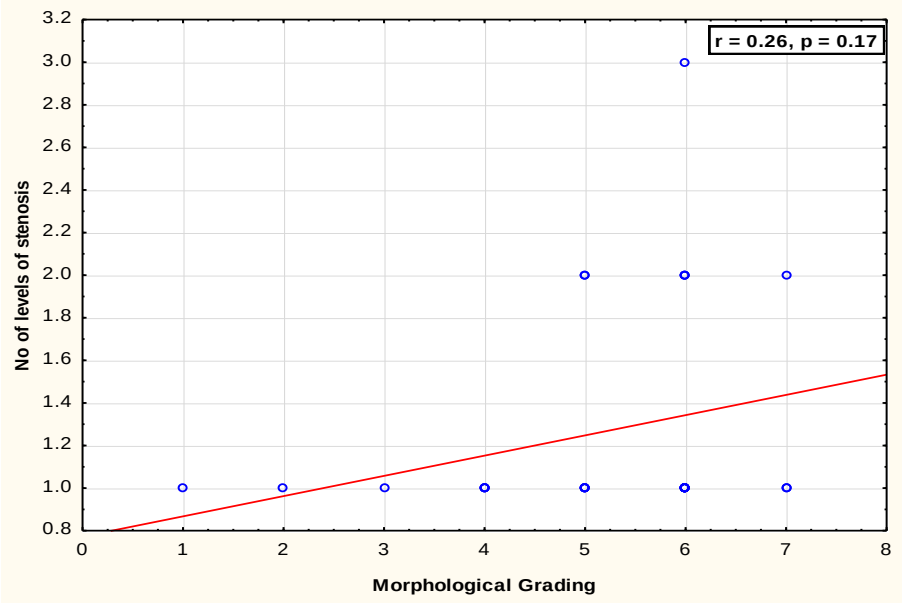


Figure 17: The relationship of No of levels of stenosis versus Morphogical grading

The 2 patients who did not have positive sedimentation had a lower Morphological grading and the level involved was L4L5 and it was single level involvement.

4.4.4.3 Morphological grading and Hamanishi cross sectional area

Dural sac cross sectional area as per Hamanishi, versus morphological grading showed a positive linear relationship with an r value of 0.38, which was significant with a p value of 0.04. (Figure 18)

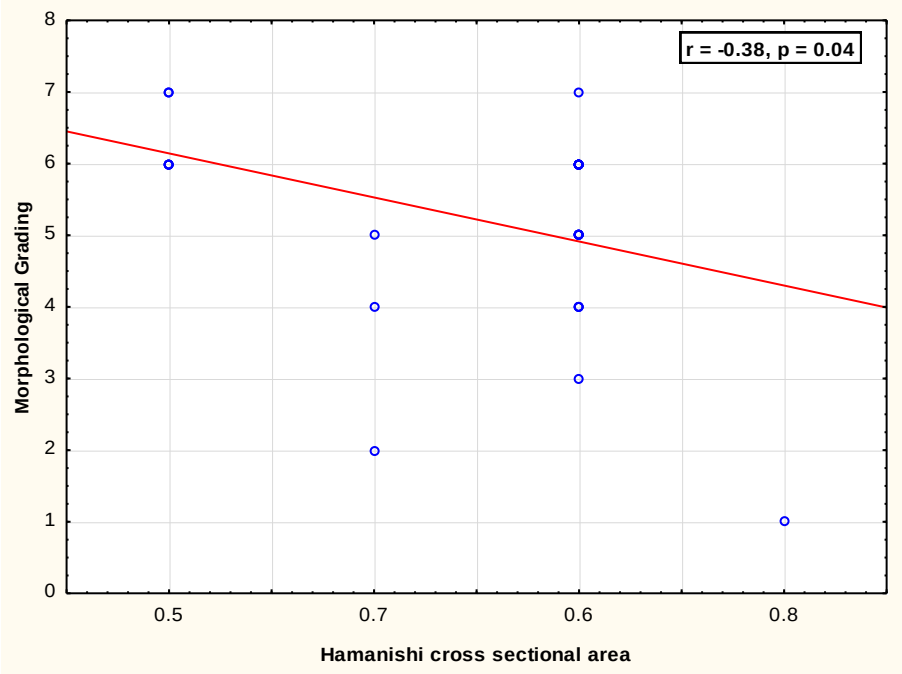


Figure 18: Morphological grading versus Hamanishi cross sectional area

4.4.5 Patient administered questionnaires

The relationship between Oswestry Disability Index and Neurogenic Claudication Outcome Score was linear with an r value of -0.6 which was significantly negatively correlated with a p value of 0.0004 (figure 18). Either questionnaire can be used to assess clinical function.

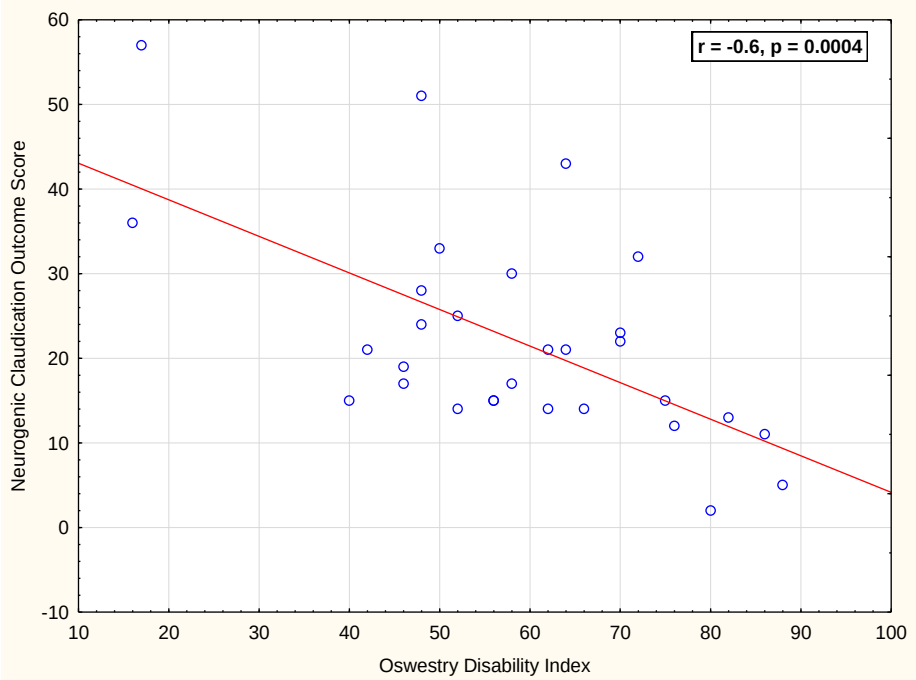


Figure 19: Oswestry Disability Index versus Neurogenic Claudication Outcome Score

Chapter 5

Discussion

5.1 Summary of results

There was female, Caucasian predominance in the study population with most patients being pensioners owing to advanced age of presentation. Majority of patients had walking distance less than 500m and were functionally disabled with regards to ODI and NCOS. L4L5 was the commonest level of stenosis. MRI features of spinal stenosis correlated amongst themselves but did not correlate with walking distance or clinical outcome scores.

5.2 Demographics

Mean age of presentation of spinal stenosis in our study is more or less similar to other studies and there was a wide range of age of presentation (43 to 85 years, mean 63.9 ± 10.39). Sirvanci et al., 2008, documented a range of 43 – 85 years with a mean of 69 years, Sigmundsson et al had a range of 34 – 89 years (mean 71years), and his older age patients had shorter walking distance.[32,33] Ogikubo et al., 2007, had a range of 33 – 84 years with a mean of 64 years.[34] There is also increasing prevalence of stenosis with age observed by these authors. Female predominance is also the trend .[32,33,34]

5.3 Radiologic observations

5.3.1 Level of stenosis and number of levels of stenosis

In this study L4L5 level is the most common level of presentation of spinal stenosis followed by L3L4 which is in keeping with literature. Patients older than 70 years had L3L4 involvement of spinal stenosis.[32,33,34] Johnsson et al., 1997, have observed proximal distribution of degeneration with ageing.[35] This study showed 23% prevalence of multilevel stenosis. Sigmundson et al., 2011, had a higher prevalence of multilevel stenosis, 54 out of 109 patients (50%).[33]

They found that the patients had a more favorable level of general health than single level stenosis despite having smaller dural sac cross sectional area.[33] In our study 10% of the patients had stenosis above L3 and it was prevalent in older patients. [33,35]

5.3.2 Dural cross sectional area

In this study the Hamanishi technique was used to calculate the cross sectional area and patients with walking distance greater than 200m were included.[23] Our study population did not demonstrate correlation between walking distance and canal width. Ogikubo et al., 2007, compared the dural sac cross sectional area to preoperative symptoms in patients with central lumbar spinal stenosis.[34] Their study found a correlation between the severity of cauda equina and walking ability and pain intensity in the back and leg.[34] Smaller cross sectional area was related to shorter walking distance and was not related to age, gender or duration of symptoms.[34] The walking distance was not objectively assessed. Johnson et al., 1997, did not find any correlation but walking distance did correlate with canal width in their study.[35]

5.3.3 Sedimentation sign

A positive sedimentation sign was found in 94% of our study population. Barz et al., 2010 and Staub et al., 2011. Barz et al., 2010, had similar findings. Their findings revealed a positive sedimentation sign in lumbar spinal stenosis and absence in the lower back pain group.[26,27] Macedo et al., 2013, in their study concluded that sedimentation sign is a diagnostic indicator for central spinal stenosis but they did not correlate it clinically.[36]

5.3.4 Morphological grading

Henderson et al.,2012, have shown that morphological grading showed significantly less variability with slice orientation than dural sac cross sectional area.[22] It is thus a more reliable marker of radiological severity. It has an interobserver variability with a kappa value 0.7. However dural sac cross sectional area has better interobserver agreement than morphological grading with a kappa value of 0.71.[22] Interobserver and intraobserver variability was however not assessed in this study.

5.4 Patient administered Questionnaires

In our study 43% of patients had severe grading of the Oswestry Disability Index. Sirvanci et al., 2008, also had 40% of the study population with severe grading.[32] They had 49% response rate for the sex life question and in our study it was 83%.

The Neurogenic Claudication Outcome Score had similar findings with regards to sex life question.

5.5 Correlations of radiological features and patient administered questionnaires

In this study a second questionnaire, the Neurogenic Claudication Outcome Score, was used as well to see if any correlation could be established with radiological findings. The questionnaires were negatively correlated with moderate significance. Increasing score as per Oswestry Disability index suggests worsening clinical function and decreasing score in Neurogenic Claudication Outcome Score refers to worsening function.

Schizas et al., 2010 found no correlation between Oswestry Disability Index and morphological grading and there was no increase in severity in multilevel stenosis.[24,25]

Sirvanci et al., 2008, did not find any correlation between Oswestry Disability Index and Magnetic Resonance Imaging.[32] Similarly, in our study population there was also no correlation in with regards to radiological parameters and functional scores.

Area measurements fail to take into account the degree of neural tissue entrapment. It has been hypothesized that neural tissue adapts to stenosis with time and degree of stenosis thus does not correlate clinically.[37,38] Variations in canal size and preexisting developmental stenosis affect the clinical presentation as well.[37,38] Multilevel involvement did not appear to increase severity of clinical presentation, as analyzed by patient administered questionnaires, in this study. This further adds to the variability of populations and clinical presentation. Sirvanci et al., 2008, postulated psychosocial issues of patients, like depression, as a reason for lack of correlation between clinical and radiological factors in their study.[32]

5.6 Limitations of the study

There was no distinction made between central or lateral stenosis. Magnetic Resonance imaging scans were done supine and thus static. The L5S1level of stenosis was not included in the study due to distribution of the nerve roots and poor rootlet content.

Chapter 6

Conclusion

Our findings, like previous studies, confirm that clinical findings correlate poorly with radiological findings and the diagnosis thus remains primarily a clinical one. Spinal stenosis remains the most frequent indication for spine surgery in patients older than 65 years of age. There are currently no universally accepted diagnostic criteria for spinal stenosis. Variations in canal size in populations, static imaging and multiple values of quantifying degree of narrowing also have a bearing on diagnosis. The psychological aspect of back pain, which also affects the functionality of the patients and thus the Oswestry Disability score, makes clinical correlation unreliable. Symptoms tend to fluctuate over time and this may have an impact on clinical correlation as reported in various studies.[32,33,34,35]

Sedimentation sign and morphological grading have been added to radiological markers of spinal stenosis. There are other causes of spinal stenosis and it would be of interest to review the Magnetic Resonance Imaging to assess the sedimentation sign and morphological grading which will help with specificity of the observations. Clinical relevance and significance of radiological findings, however still remains a challenge.[23,36]

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Appendix

1. Anatomy of lumbar nerve root ii
2. Dural sac morphology iii
3. Morphological grading iv
4. Oswestry Disability Index v
5. Neurogenic Claudication Outcome Score viii
6. Ethics Approval x

Appendix 1- Normal anatomy of the lumbar nerve roots (Cohen et al,1999)[1]

CONTRAST-ENHANCED CT SCAN | SURFACE-COIL MRI | ANATOMICAL DIAGRAM

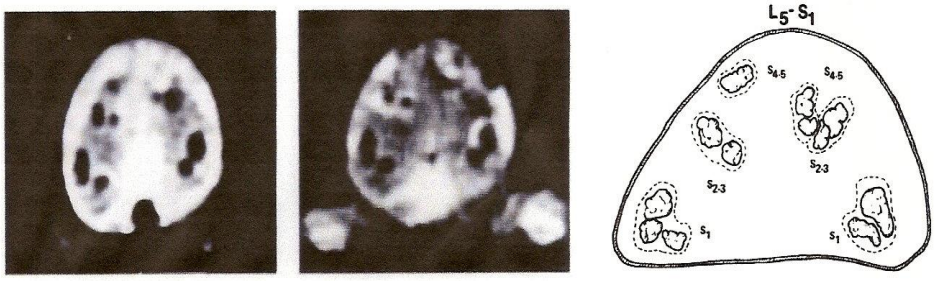


Fig. 1a Fig. 1b Fig. 1c

L5-S1 intervertebral level. A crescentic pattern of nerve roots is seen within the thecal sac, with the S1 root lying anterior and lateral.

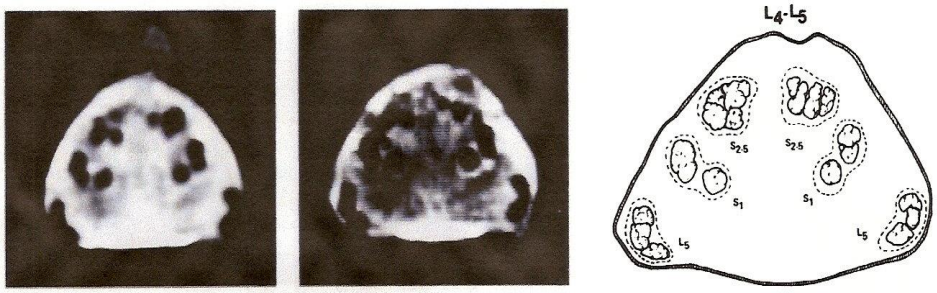


Fig. 2a Fig. 2b Fig. 2c

L4-L5 intervertebral level. The L5 root is situated anterolaterally, displacing the S1 root, and the lower sacral roots are positioned dorsally. There is clear separation of the motor (anterior and medial) and sensory (posterior and lateral) roots.

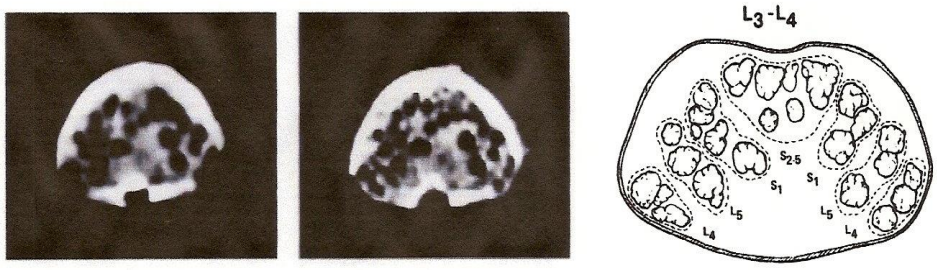


Fig. 3a Fig. 3b Fig. 3c

L3-L4 intervertebral level. Although the anatomy is more crowded, the motor bundles of the L4, L5 and S1 nerve roots are visible anterior and medial to their corresponding multifascicular sensory bundles.

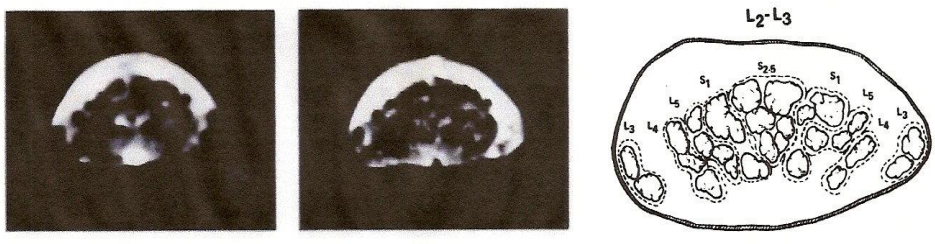


Fig. 4a Fig. 4b Fig. 4c

L2-L3 intervertebral level. The roots occupy most of the thecal sac at this level, with the motor bundle anterior to its sensory counterpart for each root.

Appendix 2- Hamanishi dural sac morphology (Hamanishi et al, 1994)[23]

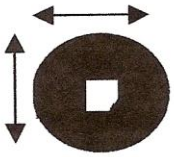
Measure the greatest medio-lateral (*A*) and antero-posterior (*B*) diameters of the common dural sac on the axial MRI cut.

AxB=C (preliminary area).

If the dural tube shape is :

- Round or eliptical :

  True Area=0.8xC



- Slightly impacted by facets :

  True Area=0.7xC



- Trigonal secondary to signifcant facet overgrowth :

  True Area=.6xC



- Trigonal as above with significant disc bulge :

  True Area=.5xC

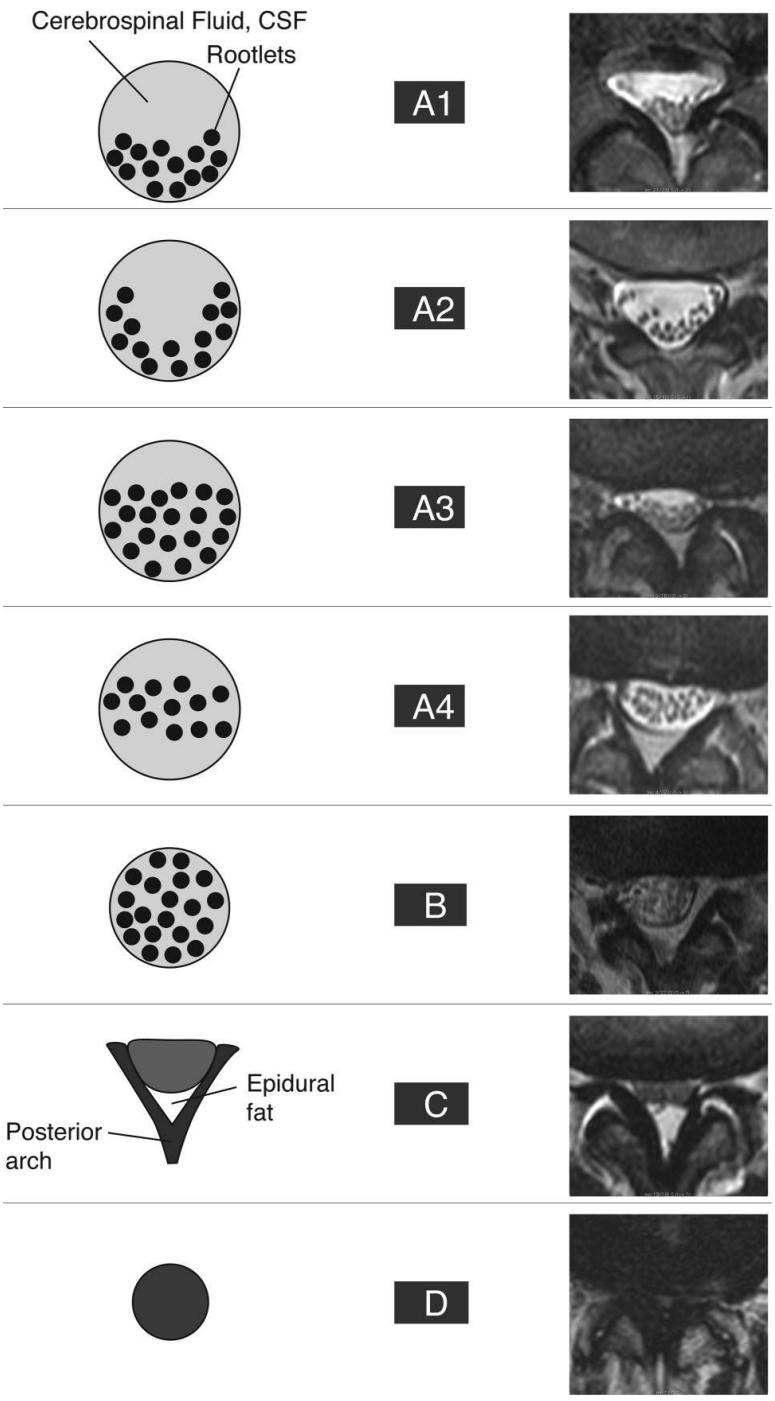


Note : If axial cut is >20 degrees from parellel to the disc space,

B'=B x Cos of angle off parrelel and *B'* is substituted into the initial equation for *B*.

This additional calculation was indicated in five of the cases studied.

Appendix 3- Morphological grading (Schizas et al, 2010)[24]



Appendix 4- Oswestry Disability Questionnaire (Fairbank, 2000) [26]

A. OSWESTRY DISABILITY QUESTIONNAIRE VERSION 2.0

PLEASE JUST CIRCLE THE ONE CHOICE, WHICH MOST CLOSELY DESCRIBES YOUR PROBLEM RIGHT NOW.

SECTION 1 – Pain Intensity

A. I have no pain at the moment.

B. The pain is very mild at the moment.

C. The pain is moderate at the moment.

D. The pain is fairly severe at the moment.

E. The pain is very severe at the moment.

F. The pain is the worst imaginable at the moment.

SECTION 2 – Personal Care (washing, dressing, etc.)

A. I can look after myself normally without causing extra pain.

B. I can look after myself normally but it is very painful.

C. It is painful to look after myself and I am slow and careful.

D. I need some help but manage most of my personal care.

E. I need help everyday in most aspects of self-care.

F. I do not get dressed, wash with difficulty and stay in bed.

SECTION 3 – Lifting

A. I can lift heavy weights without extra pain.

B. I can lift heavy weights, but it causes extra pain.

C. Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, e.g., on a table.

D. Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently placed.

E. I can only lift very light weights, at the most.

F. I cannot lift or carry anything at all.

SECTION 4 – Walking

A. Pain does not prevent me from walking any distance.

B. Pain prevents me from walking more than 1 kilometer.

C. Pain prevents me from walking more than ½ kilometer.

D. Pain prevents me from walking more than ¼ kilometer.

E. I can only walk while using a cane or crutches.

F. I am in bed most of the time and have to crawl to the toilet.

SECTION 5 – Sitting

A. I can sit in any chair as long as I like without pain.

B. I can only sit in my favourite chair as long as I like.

C. Pain prevents me from sitting more than one hour.

D. Pain prevents me from sitting more than ½ hour.

E. Pain prevents me from sitting more than 10 minutes.

F. Pain prevents me from sitting at all.

SECTION 6 – Standing

A. I can stand as long as I want without extra pain.

B. I can stand as long as I want but it gives me extra pain.

C. Pain prevents me from standing for more than 1 hour.

D. Pain prevents me from standing for more than ½ an hour.

E. Pain prevents me from standing for more than 10 minutes.

F. Pain prevents me from standing at all.

SECTION 7 – Sleeping

A. My sleep is never disturbed by pain.

B. My sleep is occasionally disturbed by pain.

C. Because of pain, I have less than 6 hours sleep.

D. Because of pain, I have less than 4 hours sleep.

E. Because of pain, I have less than 2 hours sleep.

F. Pain prevents me from sleeping at all.

SECTION 8 – Sex life

A. My sex life is normal and causes no extra pain.

B. My sex life is normal, but causes some extra pain.

C. My sex life is nearly normal but is very painful.

D. My sex life is severely restricted by pain.

E. My sex life is nearly absent because of pain.

F. Pain prevents any sex life at all.

SECTION 9 – Social Life

A. My social life is normal and gives me no pain.

B. My social life is normal but increases the degree of my pain.

C. Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g., dancing, sport, etc.

D. Pain has restricted my social life and I do not go out very much.

E. Pain has restricted my social life to my home.

F. I have hardly any social life because of the pain.

SECTION 10 – Traveling

A. I can travel anywhere without pain.

B. I can travel anywhere but it gives extra pain.

C. Pain is bad but I manage journeys over 2 hours.

D. Pain restricts me to journeys of less than one hour.

E. Pain restricts me to short necessary journeys less than 30 minutes.

F. Pain prevents me from travelling except to receive treatment.

Appendix 5- Neurogenic claudication outcome score (Weiner et al, 1999)[29]

1. How far can you walk before having to stop and rest?

a. < 100 meters

b. Between 100m and 500 meters

c. Between 500m and 1kilometer

d. > 1kilometer

2. How long can you stand still before having to sit down?

a. < 5 minutes

b. 5 to 15 minutes

c. 15 to 45 minutes

d. As long as I please

3. Once your symptoms arise, you have:

a. Severe

b. Moderate

c. Mild

d. None

Rank each: Back pain, leg pain, numbness/tingling, heaviness/weakness

4. The symptoms affect the following activities:

a. Severely

b. Moderately

c. Mildly

d. Not at all

Rank each: sports or activities, household or odd jobs, walking, standing, sitting, sex life

5. How long must you rest before the symptoms resolve?

a. > 10 minutes

b. Between 5 and 10 minutes

c. < 5 minutes

6. How frequently do you take pain medicine for these symptoms?

a. Frequently

b. Daily

c. Occasionally

d. Never

7. How frequently do you see a doctor for these symptoms?

a. Frequently

b. Monthly

c. Rarely

d. Never

8. Rank your pain on the following scale:

1	2	3	4	5	6	7	8	9	10
No pain								Worst pain	

Appendix 6: Ethics approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Dr Leah D Ramushu

CLEARANCE CERTIFICATE	**M10218**
PROJECT	Presentation of Cauda Equina in Patients with with Degenerative Lumbar Spinal Stenosis on MRI Axial Cuts and linical Correlation Thereof
INVESTIGATORS	Dr Leah D Ramushu.
DEPARTMENT	Division of Orthopaedic Surgery
DATE CONSIDERED	26/02/2010
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 07/04/2010 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Prof M Lukhele

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...