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Decompression vs. Decompression and Fusion in Cauda Equina Syndrome Secondary to Massive Lumbar Disc Herniation

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Surgery

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ABSTRACT

Posterior spinal surgery through either a decompression or additional fusion procedure is the widely accepted standard of care for patients presenting with cauda equina syndrome (CES) secondary to massive disc herniation. A plethora of literature has been published regarding post-surgical outcome, particularly in regards to improvement of lower sacral nerve symptoms in relation to timing of surgery. There is a paucity of data with regards to long term clinical outcomes in patients between the decompression and decompression and fusion groups. We initially hypothesized that there would be no longer term clinical differences in outcome between the two groups, which was the objective of this thesis. The initial post-operative data showed no statistically significant difference between the decompression and fusion groups with regards to lower extremity weakness, presence of radicular symptoms, and improvement in lower sacral symptoms, those being bladder, bowel, and sexual function. Our long-term follow up cohort yielded patients from the decompression group alone and showed general trends of improvement from their initial presentation in the aforementioned domains.

KEYWORDS

Cauda Equina Syndrome, Decompression, Adult Spinal Fusion, Lumbar Spine, Long term outcomes, Lumbar disc herniation, intervertebral disc, discectomy

SUMMARY FOR LAY AUDIENCE

Cauda equina syndrome (CES) is a debilitating condition from compression of the nerves in the lower portions of the spine. This compression can be from a variety of pathologies, but massive disc herniation will be the focus of this thesis. The compression of the nerves leads to a constellation of symptoms that are seen clinically, which include lower extremity motor difficulties, changes in sensation in the lower extremities, as well as changes in bladder, bowel, and sexual function. This specific condition is extremely rare and is thought to account for less than 5% of all lumbar spine surgeries with new cases presenting in the range of 1 in 33,000 to 1 in 100,000. The goals of therapy are to relieve the compression on the nerves, which is achieved through a posterior spinal surgery. This surgery usually involves removing a piece of the bone in the back of the spine to allow for decompression around the sac filled with the nerves, as well as removing parts of the herniated disc material that is contributing to the compression. In some cases, patients have pre-existing spinal deformity, or a large amount of disc needs to be removed along with a wider decompression that may affect the overall stability of the spine. In these cases, a fusion procedure is added to help address this. In this procedure, screws are placed into the building blocks of the spine called vertebrae with metal rods that are placed into the screw heads to hold things in place.

The decompression procedure is shorter in terms of operative time, and thereby can have the added benefit of lower infection rates, and theoretically lower complications long term. In addition, given the lack of implanted hardware, there is a lower cost and risk for problems at the vertebral levels that are close by, known as adjacent segment disease. However, it has been seen in the past that lumbar fusion can help with lower back pain, which is something that is seen in the population presenting with cauda equina syndrome. To truly understand the clinical differences, we arranged long term in person follow up and administered questionnaires that allowed us to document a variety of different functional domains, from self-care to exercise tolerance to name a few, and return of control of their bladder and bowel function alongside return of power in their legs. We initially found that there was no true difference between the two procedures in the shorter-term post operative follow-up and that overall longer-term trends in the decompression alone group were positive.

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CO-AUTHORSHIP STATEMENT

This thesis was a joint effort with contributions as follows.

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Chapter 2:

Ruheksh Raj – study design, data collection and analysis, manuscript writing

Chris Bailey – reviewed study design, collection, analysis, manuscript

Jen Urquhart – reviewed study design

Chapter 3:

Ruheksh Raj – results, tables, data analysis, manuscript writing

Chris Bailey – reviewed results, tables, data analysis, manuscript

Jen Urquhart – reviewed tables

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Ruheksh Raj – Sole Author

TABLE OF CONTENTS:

ABSTRACT	I
KEYWORDS	II
SUMMARY FOR LAY AUDIENCE	III
ACKNOWLEDGEMENTS	IV
CO-AUTHORSHIP STATEMENT	V
TABLE OF CONTENTS:	VI
LIST OF FIGURES	VIII
LIST OF TABLES	IX
1. INTRODUCTION	1
1.1 SPINE STRUCTURAL ANATOMY	1
1.2 SPINAL CORD AND NERVE ROOT ANATOMY	3
1.3 INTERVERTEBRAL DISC ANATOMY	5
1.4 CAUDA EQUINA SYNDROME	7
1.5 SURGICAL MANAGEMENT OPTIONS	9
1.6 THESIS RATIONALE	14
2. METHODS	15
2.1 PATIENT SELECTION	15
2.1.1 INCLUSION CRITERIA.....	15
2.1.2 EXCLUSION CRITERIA	15
2.2 RADIOGRAPHIC ANALYSIS	16
2.3 BASELINE PATIENT CHARACTERISTICS	17
2.4 PATIENT INTERVIEW	18
2.5 STATISTICAL ANALYSIS.....	18
3. RESULTS	19
3.1 PRE-OPERATIVE BASELINE DEMOGRAPHICS.....	19
3.2 PRE-OPERATIVE FUNCTIONAL ASSESSMENT	21
3.3 PRE-OPERATIVE RADIOGRAPHIC PARAMETERS.....	23
3.4 IMMEDIATE POST-OPERATIVE FUNCTIONAL RESULTS	25
3.5 LONG TERM FOLLOW UP BASELINE DEMOGRAPHIC DATA.....	27
3.6 LONG TERM FOLLOW UP PATIENT REPORTED OUTCOME MEASURES	28
3.7 LONG TERM FOLLOW UP CLINICAL EXAMINATION FINDINGS	28
4. DISCUSSION	31
4.1 SUMMARY AND DISCUSSION.....	31
4.2 LIMITATIONS AND FUTURE DIRECTIONS.....	35
4.3 CONCLUSION	36
REFERENCES:	37
APPENDICES:	41
A) FLOWCHART OF PATIENT SELECTION	41

B) OSWESTRY DISABILITY INDEX QUESTIONNAIRE	42
C) NUMERICAL RATING SCALE TOOL	43
D) SF-12 QUESTIONNAIRE	44
E) FIM INSTRUMENT	47
CURRICULUM VITAE	48

LIST OF FIGURES

FIGURE 1: LUMBAR VERTEBRAE	2
FIGURE 2: NEURAL ANATOMY	4
FIGURE 3: INTERVERTEBRAL DISC ANATOMY	7
FIGURE 4: SURGICAL TECHNIQUES	12
FIGURE 5: LUMBAR SPINAL FUSION	13
FIGURE 6: PFIRRMANN GRADING OF DISCS	17

LIST OF TABLES

TABLE 1: PRE-OPERATIVE BASELINE DEMOGRAPHICS.....	20
TABLE 2: PRE-OPERATIVE FUNCTIONAL ASSESSMENT	22
TABLE 3: PRE-OPERATIVE RADIOGRAPHIC PARAMETERS	24
TABLE 4 - INITIAL POST-OPERATIVE FUNCTIONAL RESULTS	26
TABLE 5 - LONG-TERM DEMOGRAPHIC RESULTS	27
TABLE 6 - LONG TERM FOLLOW UP CLINICAL AND PATIENT RATED OUTCOMES	29
TABLE 7 - LONG TERM LOWER SACRAL SYMPTOM RESOLUTION	30
TABLE 8 – LONG TERM RADIOGRAPHIC AND RE-OPERATION PARAMETERS.....	30

1. INTRODUCTION

This chapter will provide a brief outline of general spinal anatomy, focus on intervertebral disc anatomy, and outline the pathological processes behind the disease along with current concepts in treatment modalities.

1.1 SPINE STRUCTURAL ANATOMY

The human spine is made up of a column of individual bones called vertebrae. These vertebrae can be grouped into 5 major sections based on their location. These are the cervical, thoracic, lumbar, sacral, and coccygeal regions. The cervical region comprises of 7 bones, thoracic with 12 bones, lumbar with 5 bones. There are 5 fused bones comprising the sacrum and the additional coccyx. The vertebral body is the main weightbearing region of the spinal column and is over which the intervertebral discs over-lie. From the anterior vertebral body arise two pedicles, which act as connections between the anterior and posterior portions of the bony anatomy. The posterior complex includes 2 laterally projecting transverse processes, lamina, the facet joints, and the spinous processes. The joining of these two portions creates a ring-like structure in which the spinal cord (in the upper cervical and thoracic segments) and nerve roots (in the lumbosacral segments) occupy. For the purpose of this thesis, we will be focusing on the lumbar spine anatomy and pay particular attention to the structure and function of the intervertebral disc. (Figure 1)^{1,2}

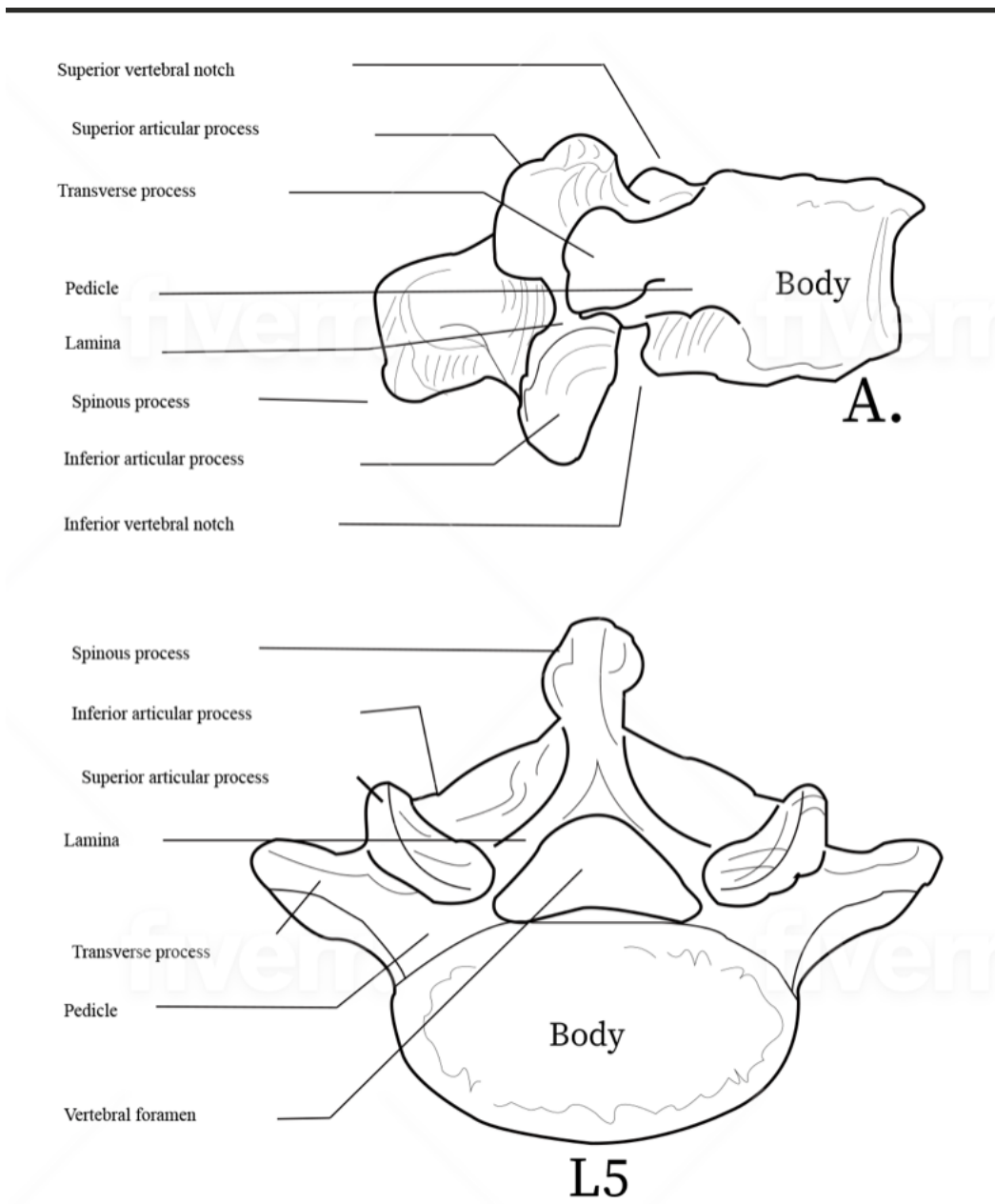


Figure 1: Lumbar Vertebrae

This image shows the anatomy of a lumbar vertebral body at the level of L5. The top lateral view shows the body anteriorly, the pedicles, and the articular processes, which form the facet joints to the adjoining vertebrae and allow for joint movement. The lower axial image shows the formation of a ring structure with the vertebral foramen being the location of the neural elements centrally.

1.2 SPINAL CORD AND NERVE ROOT ANATOMY

The spinal cord is the extra-cranial extension of the central nervous system. It runs from the brainstem down to its terminal region called the conus medullaris. This is usually at the thoracolumbar junction. Past the conus medullaris lies the cauda equina, once referred to as horse's tail, which is what it resembles. The cauda equina itself is a combination of the second to the fifth lumbar nerve roots and rootlets, along with the 5 sacral nerve roots and the coccygeal nerve. The lumbar roots have both anterior and posterior divisions. The posterior divisions terminate in the paraspinal musculature and provide innervation to these muscle groups. The anterior divisions have varying anatomic courses and form the lumbar plexus. The sacral nerve roots follow a similar anatomical course with coalescence between the lumbar nerve and the sacral leading to the formation of the lumbosacral plexus. These lumbar nerve roots primarily innervate the lower extremities in both a motor and sensory capacity. The sacral nerve roots provide innervation through a combination of somatic and autonomic nervous pathways to the rectum, anal sphincters, urinary bladder and the genital organs. (Figure 2)^{3,4,5}

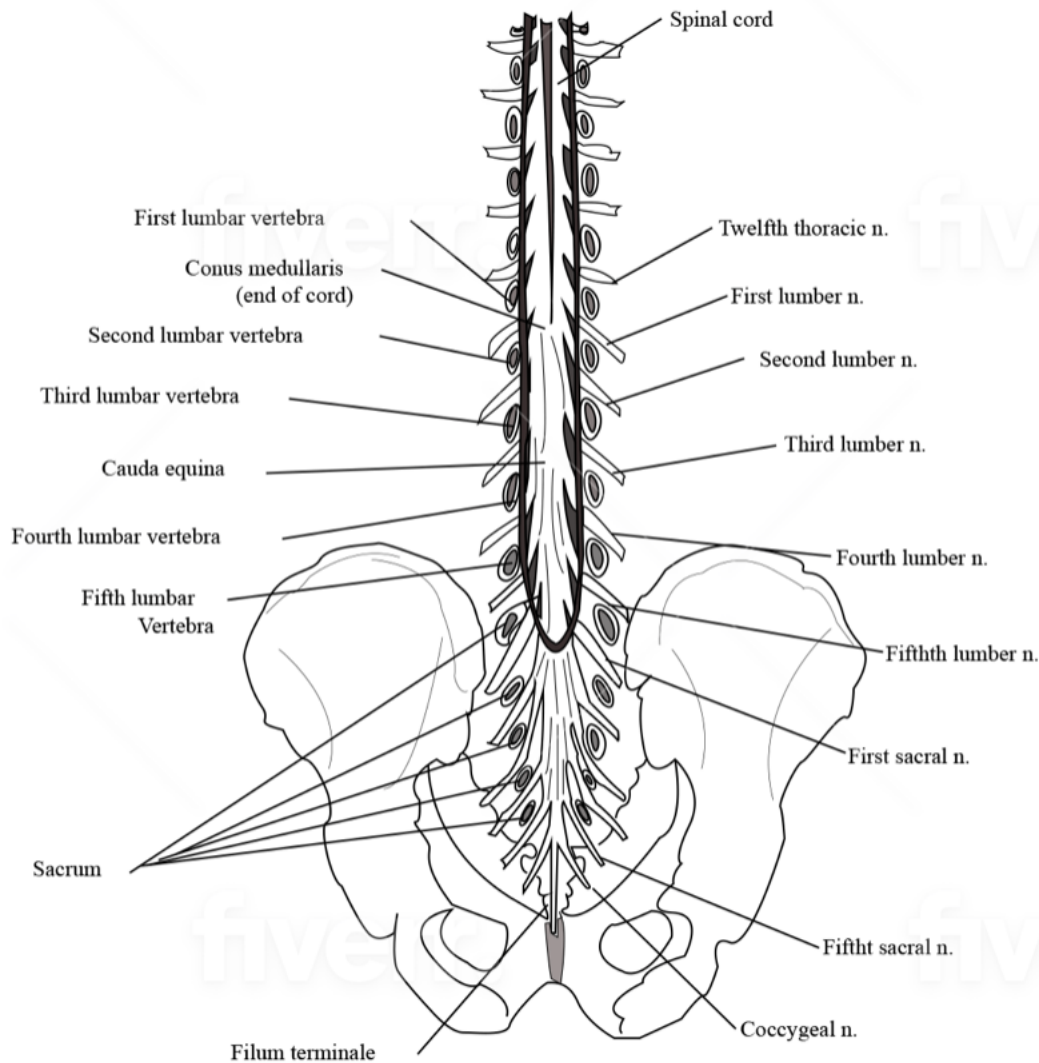


Figure 2: Neural Anatomy

This diagram shows an anterior-posterior view of the spinal cord and terminating nerve roots. The cord can be seen centrally in the canal terminating at the level of T12-L1 with the conus medullaris outlined at that region. The cauda equina is seen below this level and is the collection of the lower lumbosacral nerve roots. The roots can be seen exiting on both the left and right side to supply both the lower extremities and lower sacral functions.

1.3 INTERVERTEBRAL DISC ANATOMY

Intervertebral discs in the lumbar spine are soft tissue structures that assist with force distribution during a variety of ranges of motion, including axial loads in the spine, flexion and extension, lateral bending, and rotational movements. The discs themselves are composed of three components. These include the endplates which are cartilaginous in origin and are essentially the subchondral region of the adjoining vertebrae, the annulus fibrosis, which is an outer ring structure made up of lamellated type 1 collagen tissue, and the nucleus pulposus, which is the central portion of the intervertebral disc comprised of type 2 collagen and proteoglycans. The outer annulus has high tensile strength with the inner nucleus dealing with the axial load component of stress. There is a high level of demand on these structures particularly in the lumbar region and the disc material is a relatively avascular structure. The majority of the blood supply is from nutrient arteries encircling the outer aspect of the disc with contributions from the capillaries originating in the neighbouring vertebral bodies. As the disc reaches the limits of its stress, herniations become common and significant herniations have less chance of complete remodelling and healing without intervention.^{6,7}

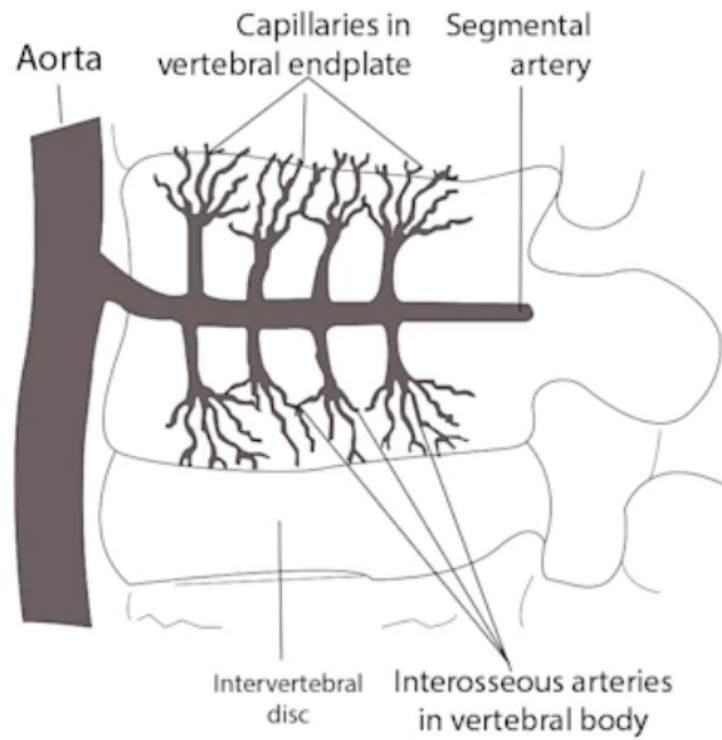
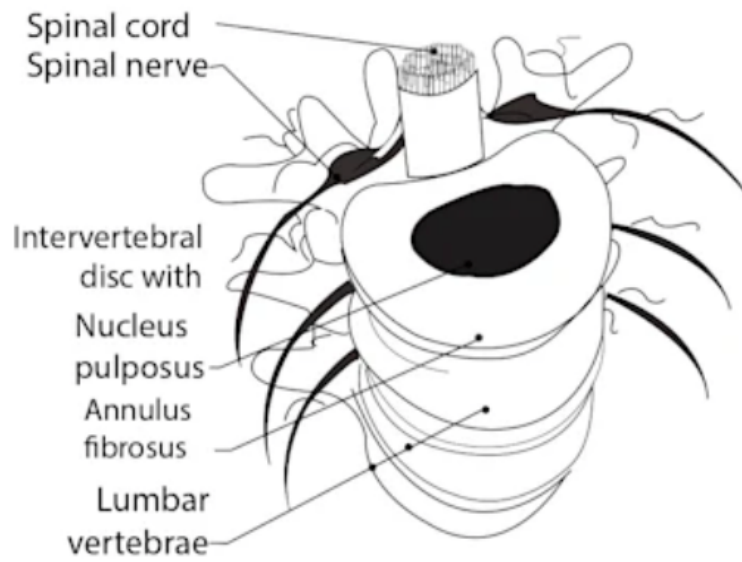


Figure 3: Intervertebral Disc Anatomy

The first image shows a top down oblique view of the intervertebral disc and its relation to the bony and neural anatomy in the lumbar spine. There is an outer annulus fibrosis layer with lamellated collagen providing structural support and an inner nucleus pulposus layer which provides a cushioning effect. The image below shows the blood supply to the disc viewed from a lateral based image. This shows the diffusion process that the nutrient arteries provide to the disc for tissue oxygenation requirements. The central portion of the disc is relatively avascular.

1.4 CAUDA EQUINA SYNDROME

Cauda equina syndrome (hereafter CES) is a condition that occurs due to disruption of the lower lumbosacral nerve roots below the spinal cord. The syndrome comprises of a constellation of symptoms, including lower back pain, radiculopathy, and paraesthetic phenomena in the lower extremities. Altered reflexes in the lower extremity can also be elucidated on physical examination. Furthermore, there is lower sacral root involvement yielding perianal sensory disturbances, as well as potentially bladder, bowel, and sexual dysfunction.⁸

CES can be further subdivided into two main categories based on the lower sacral root symptoms. CES is considered incomplete (CES-I) when the patient has altered urinary sensation as well as urinary difficulties along with unilateral saddle and genital sensory disturbance. CES is considered complete or retentive (CES-R) when compression leads to painless urinary retention, overflow symptoms of incontinence, and significant saddle and genital sensory disturbance. It has been clearly established in the literature that there are favorable outcomes for those patients who initially present with a CES-I rather than those in the retention group in terms of symptom resolution as well as neurologic recovery and subsequent function.^{9,10}

There are a variety of aetiologies that theoretically can lead to the development of this syndrome. These can range from lumbar disc herniations, spinal stenosis, neoplastic or proliferative causes,

infection leading to epidural abscess and iatrogenic causes. The focus of this thesis will be CES secondary to massive lumbar disc herniation.¹¹

Epidemiological studies have been performed to determine potential risk factor associations to significant lumbar disc herniations. The SPORT trial reported that combined average age for disc herniations was 41.7 with a slightly higher male predominance in comparison to women which was quoted as 57% and 43% respectively combined between both arms. A meta-analysis by Shiri et al. also clearly showed that both overweight (BMI 25-29) and obese (BMI >30) was consistently associated with an increased risk of sciatica with the majority of the population being secondary to lumbar intervertebral disc pathologies. Another meta-analysis of 37 systematic reviews by Jordan et al. showed a significant clear association with smoking and disc herniation (OR 1.7, CI 1.0-2.7).^{6, 12, 13, 14}

Timing to surgery as a prognostic factor for neurologic recovery has been well described in the literature. Shapiro conducted a retrospective analysis of 44 patients presenting with CES. Twenty patients underwent decompressive surgery within 48 hours of syndrome onset with 18 of those patients undergoing surgery within the first 24 hours. 95% of patients presented with bilateral sciatica and all patients had presence of either urinary incontinence or retention, both, and saddle region hypesthesia/analgesia. Twenty-four patients within the group underwent surgery more than 48 hours after symptom onset with a mean delay of 3.7 days. Chi-square analysis yielded statistically significant increased chance of persistent bladder dysfunction (p=0.008), persistent severe motor deficit (p = 0.006), persistent pain (p=0.025) and sexual dysfunction (p=0.006) for the delayed surgical group. However, this study failed to distinguish between the incomplete CES group and those presenting with the full blown retention picture (CES-R). Another retrospective series by Kennedy et al. examined a 19 patient cohort presenting with similar neurological presentations and distributions to the Shapiro cohort. Patients with satisfactory recovery had a mean surgical time of 14 hours with the group ranging from 6-24 hours. However, like the Shapiro study, there was no delineation between CES-I and CES-R on presentation.^{15,16}

Injury to the cauda equina can theoretically be from disc herniation as high as the level of T12/L1. However, given the fact this is at the conus medullaris level, the syndrome presentation is less in

keeping with the CES that we are studying. The most commonly affected levels for a true CES are disc herniations at the L4/L5 and the L5/S1 vertebral disc levels. There is both a mechanical component to the nerve injury as well as an ischaemic insult to the fibres. The mechanical compression is noted to affect the smaller fibres usually affecting pain sensation and parasympathetic function in comparison to the larger calibre fibres which carry motor, sensory, and proprioceptive information. This compression can also lead to deficiencies in axoplasmic flow and in conjunction with changes in arterial flow and venous congestion, lead to nerve impulse propagation abnormalities and the resultant clinical symptoms. Therefore, the key to creating a milieu for nerve healing and potential regeneration rests with relief of the compression.¹⁰

1.5 SURGICAL MANAGEMENT OPTIONS

Posterior lumbar surgery is the definitive treatment option for CES. Lumbar decompression can be performed via addressing a variety of the anatomic structures either in isolation, or in combination. A laminectomy is a procedure that can be performed to address compression posteriorly. In this procedure, the lamina is removed either unilaterally or bilaterally to achieve the decompression. In the setting of disc herniation, a discectomy, where the herniated disc material is excised, is routinely performed in conjunction with the aforementioned laminectomy in order to obtain adequate decompression. (Figure 4)^{17,18}

In certain instances, there is a need for a wider decompression and the motion segments of the facet joints are violated in order to achieve this decompression. In this instance, a spinal fusion will be performed on top of the aforementioned decompression. The commonly used instrumentation involves screws that are placed into the pedicles and seat in the vertebral body with rods that are locked into place on top of the screw heads. Bone graft, either autograft or allograft is then placed around prepared bony surfaces to promote bone healing and lead to the fused, now immobilized segment. (Figure 5)¹⁹

Dave et al. performed a retrospective analysis in 64 patients with CES who underwent either decompression or a fusion procedure, in the heterogenous setting of pre-existing lumbar spinal stenosis with or without disc herniation. 37 patients were in the decompression group and 27 in

the fusion group. They described statistically significant improvement in lower back pain (LBP) in the fusion group in comparison to those who underwent decompression alone. Vesicular function was also statistically significant showing improved function in the fusion group. There was also a lower overall postoperative complication rate in the fusion group. They did not find any correlation between timing of surgery and influence on recovery between the two groups. ²⁰

Laminectomy

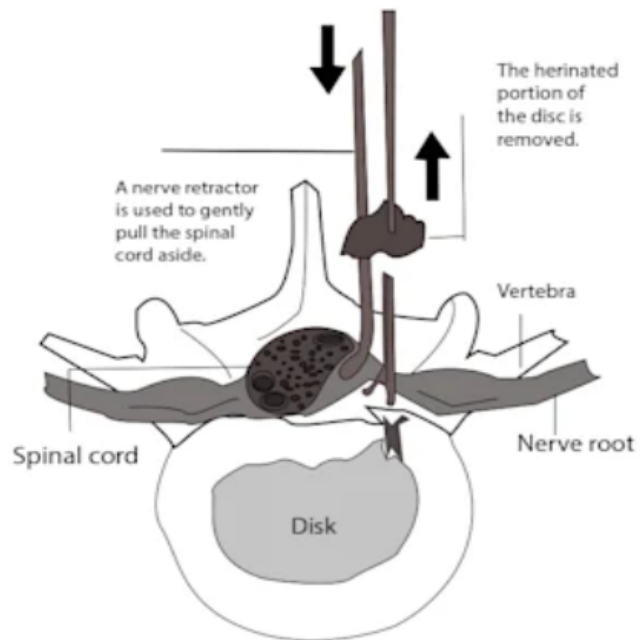
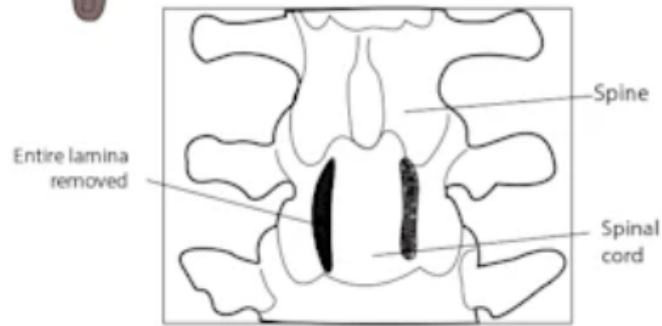
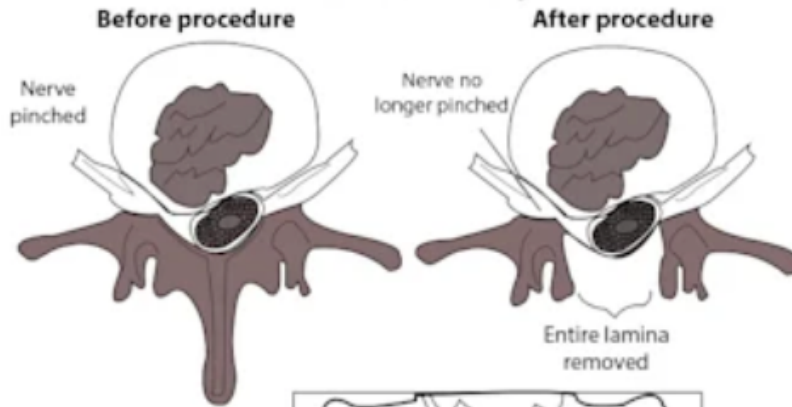


Figure 4: Surgical Techniques

The top image shows a herniated disc that is impinging on the neural elements in the lumbar spine. The procedure performed is a laminectomy which removes the bony structure posteriorly known as the lamina in order to decompress the neural elements. With large disc herniations, portions of the disc need to be removed as well. The image below shows the process of a discectomy which is performed in conjunction with the laminectomy to adequately address the compression on the neural elements.

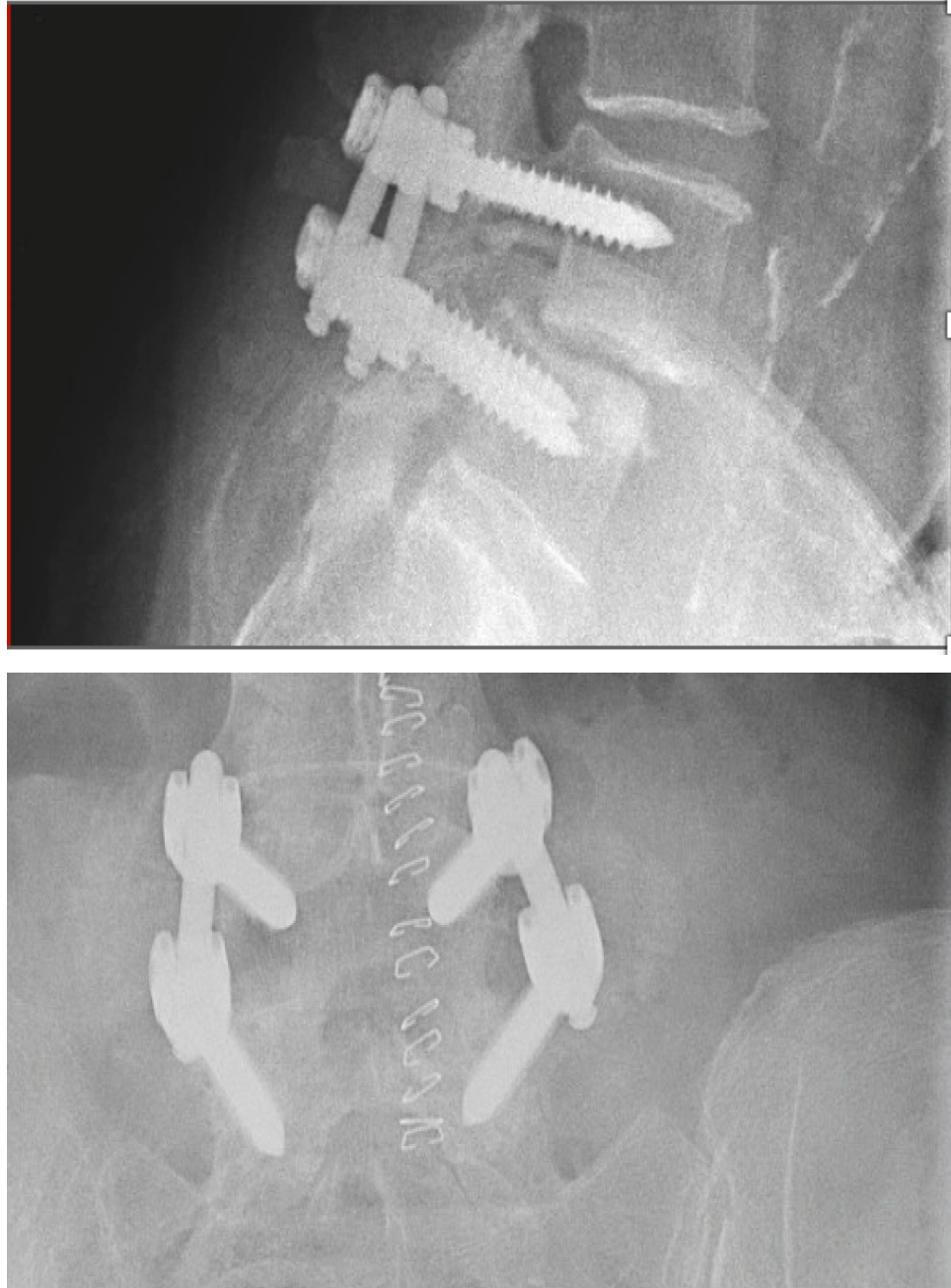


Figure 5: Lumbar Spinal Fusion

This image shows an anterior-posterior x-ray on the bottom and a lateral image on the top of a lumbar spinal fusion. The screws are placed into the vertebral bodies through the pedicles and the rods then locked onto the screws to hold the construct in place. The bone graft that is usually placed is not visible on the initial x-rays as seen above.

1.6 THESIS RATIONALE

CES remains a debilitating condition that is a definite indication for posterior decompressive surgery. There remains a paucity of evidence with regards to long term outcomes >10years in patients who underwent decompression or decompression and fusion as a treatment for CES secondary to massive lumbar disc herniation alone (>50% of the canal diameter). Dave et al. included those with degenerative stenosis and to the best of our knowledge, no other papers have sought to examine these findings. The hypothesis is that there will be improved functional outcome measures in the long term in the fusion group with regards to LBP however there will be no difference in recovery of motor, sensory, or lower sacral symptoms between the two groups. Furthermore, this study will give us insight into the population here in Canada and allow surgeons to better guide our current clinical practice when treating this disease.

2. METHODS

This chapter will outline the materials and methodology used for completion of this thesis.

2.1 PATIENT SELECTION

We began by completing our Institutional Research Ethics Board requirements. Once approved we were able to start our patient selection process. (ID 119831). Our patient selection process began by obtaining a list of all operative patients at the London Health Sciences Victoria Hospital Site within the date range of January 1, 2005 to December 31, 2015. These lists were compiled for each of the four spinal surgeons that made up our spinal surgical group. We were then able to use the N512 and E368 billing codes, for bilateral decompression and discectomy respectively, to identify potential candidates. 2846 patients were part of the initial cohort. Retrospective chart review was then performed based on our inclusion and exclusion criteria outlined below. Initial emergency room and consultation reports were reviewed to determine whether there were clinical findings of CES noted. At this point 81 patients were identified. Peri-operative documentation including operative reports were then utilized to further understand the magnitude of the condition and detail the surgical procedure that was performed, either decompression or additional fusion. Pre-operative MRI scans were reviewed for the 81 patients and in total 32 patients were included.

2.1.1 INCLUSION CRITERIA

Patients were further selected using the following inclusion criteria: that patients were aged 18 or older, there was MRI evidence of a massive disc herniation, which was defined as a disc occupying greater than 50% of the canal diameter, and that there was clear clinical documentation in terms of history and physical examination of CES.

2.1.2 EXCLUSION CRITERIA

Patients were excluded based on the following criteria. Those patients with pre-existing severe spinal stenosis from degenerative pathology based on MRI review, those patients with a previous

lumbar fusion, any patient who had previously been diagnosed with CES, and those patients with a discectomy at the involved level (i.e. L3/L4, L4/L5, L5/S1)(Appendix A)

2.2 RADIOGRAPHIC ANALYSIS

Pre-operative MRI scans were analysed to determine inclusion criteria and obtain radiographic parameters for comparison. The level affected was first determined those being the L3/L4, L4/L5 or L5/S1 levels. These levels correspond to the disc that was herniated in the lumbar and sacral regions. The image viewer system provided measurement tools allowing for determination of a variety of parameters. The average disc height at the affected level was then calculated by summing the height of the disc anterior and the height posterior and dividing that by 2. The spinal canal width was measured from the point posteriorly at the location of the posterior longitudinal ligament and the posterior aspect of the bony diametrically opposite to this point. The disc protruding into the canal was measured as well yielding an absolute value in mm. From this calculation, the percentage of the canal that this disc occupies was obtained. As aforementioned in the inclusion criteria, >50% of canal diameter occupied was the cut-off that was used. The Pfirrmann disc grading system was also applied. This is a morphologic classification that is based on T2 weighted MRI scan and uses signal intensity and disc homogeneity in order to provide a grade classified 1 through 5. The lower grades are healthier, normal discs and higher grades, degenerative. ²¹ (Figure 6)

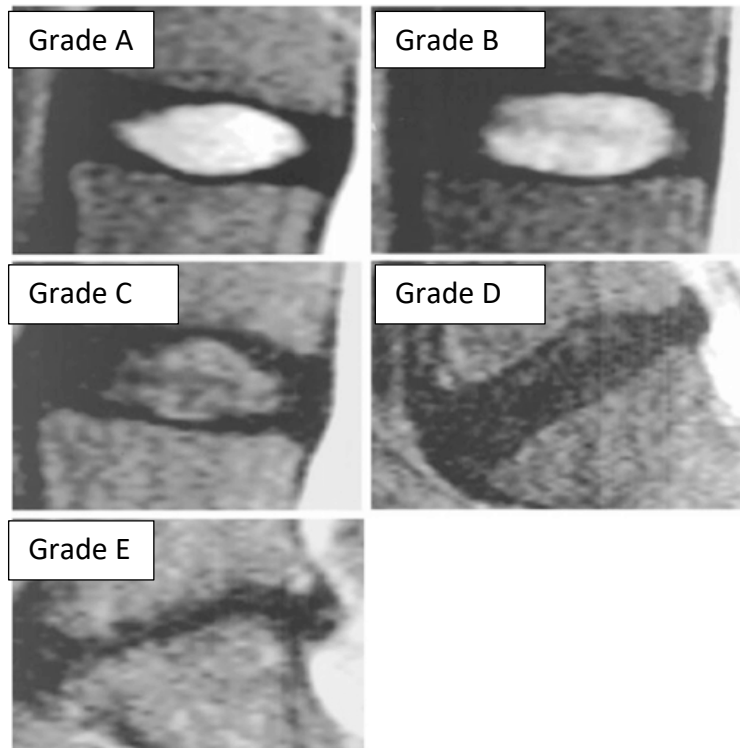


Figure 6: Pfirrmann Grading of Discs

The above image shows the Pfirrmann disc grading system that was used in order to determine the level of degeneration of the discs. Disc “Grade A” above is the lowest grade, or least degenerative disc which is seen by the bright signal in the disc material, and no heterogeneity. There is also ample disc height at this level. Progressing through the images shows increasing disc grades and increased amount of degeneration. Disc “Grade E” is the most degenerative with a loss of healthy disc material, disc height loss, and erosive endplate changes.

2.3 BASELINE PATIENT CHARACTERISTICS

Baseline demographic data was retrospectively collected. Chart review was performed and characteristics including age, BMI, smoking status, work status and surgeon performing the procedure was collected. Chart review was performed to elucidate baseline functional characteristics pre-operatively. These included presence of back pain, documentation of radiculopathy and clinical leg weakness. MRC muscle grade was obtained for each lower extremity individually. Documentation of pre-operative lumbosacral paresthesia and

urinary/bowel/sexual dysfunction was noted. Data for the initial post-operative course in terms of symptom resolution was obtained retrospectively through chart review.

2.4 PATIENT INTERVIEW

Long term follow-up ranging from 5-15 years post index surgery was then arranged following study protocol. Patients received standard of care standing lumbar x-rays at their follow up appointment prior to clinical assessment. Patients then underwent routine follow-up questions and proceeded to fill out the questionnaires provided with the physician present. The pain NRS scale, SF-12, ODI, and FIM bladder tool were answered. The NRS scale is rated from 0 to 10 where 0 is no pain and 10 is unbearable pain. This was broken down based on pain location either lower back pain or leg pain (radiculopathy). The SF-12 is a quality of life questionnaire comprised of 8 domains from the initial SF-36 that looks at varying aspects of physical and mental functioning and creates a weighted physical component and mental component score with higher scores indicating less disability.²² The ODI is a screening tool used to identify functional outcomes in 10 domains with each section being scored 1 to 5. The total score out of 50 is then turned into a percentage for overall result. The higher the ODI score the higher the level of disability. The patients underwent repeat physical examination by a single physician to determine lower extremity MRC grades. This data was tabulated.²³ (Appendices B, C, D, E)

2.5 STATISTICAL ANALYSIS

IBM SPSSv28 statistics processor was used for analysis. Groups were subdivided based on procedure performed. Statistical significance was set at $p < 0.05$. Descriptive statistical analysis was performed to determine means and standard deviation. Further data analysis was completed with the chi-square, student t-test, and fisher-exact test was performed to compare means between both groups. Frequencies tables were created to outline general trends in long term follow up data.

3. RESULTS

This chapter outlines the results of our study from both a pre-operative perspective as well as the long-term follow-up at the subsequent clinic appointment.

3.1 PRE-OPERATIVE BASELINE DEMOGRAPHICS

Table 1 outlines our baseline patient demographic results. There were 32 patients with complete information included in both our groups, those being decompression(D) (n=24) and decompression and fusion (DF) (n=8). Mean age was described as mean±SD and was 40.3±10.7 for our groups combined, 37.8±10.3 (D) and 47.8±9.0 (DF) (p<0.021). This result showed statistical significance. Sex (Female) was 15/32 of our overall group. 12 (D) and 3 (DF) (p<0.691). BMI (kg/m²)(mean±SD) was 31.2±7.0 for the overall group, 33.1±6.8 (D) and 25.6±4.3 (DF) showed statistical significance (p<0.033). Smoking status (n/%) showed 9(28.1) smokers and 12(37.5) non-smokers. 6(25) of smokers (D) and 3 (37.5) (DF). Non-smokers were 9(37.5) (D) and 3(27.5) (DF) with the comparison not being statistically significant (p<1.00). Work status n(%) was divided into three sub groups, working, unemployed, and unknown. Working was 12 (37.5) overall with 9(36.5)(D) and 3(37.5)(DF). Unemployed was 3(9.4) with 1(4.2)(D) and 2(25)(DF). Unknown was 17(53.1) with 14 (58.3)(D) and 3 (37.5)(DF) (p<0.195). Finally patient subgroups based on surgeon were also identified. 3 surgeons out of the group were included shown as n(%). Surgeon 1 was 17(53.1) overall with 15(62.5)(D) and 2(25)(DF). Surgeon 2 had 9 (28.1) overall with 4(16.7)(D) and 5(62.5)(DF). Surgeon 3 was 6 (12.5) overall with 5 (20.8)(D) and 1 (12.5)(DF) (p<0.043). This was statistically significant.

Table 1: Pre-Operative Baseline Demographics

Parameter	Overall N=32	Decompression Alone N=24	Decompression and Fusion N=8	P Value
Age, years, Mean±SD	40.3±10.7	37.8±10.3	47.8±9.0	0.021
Sex, Female, n (%)	15 (46.9)	12 (80)	3 (20)	0.691
BMI, kg/m², Mean±SD	31.2±7.0	33.1±6.8	25.6±4.3	0.033
Smoking Status, n (%)				1.000
Smoker	9 (28.1)	6 (25.0)	3 (37.5)	
Non-smoker	12 (37.5)	9 (37.5)	3 (37.5)	
Unknown	11 (34.4)	9 (37.5)	2 (25.0)	
Work Status, n (%)				0.195
Working	12 (37.5)	9 (36.5)	3 (37.5)	
Not Working	3 (9.4)	1 (4.2)	2 (25.0)	
Unknown	17 (53.1)	14 (58.3)	3 (37.5)	

Surgeon, n (%)				
1	17 (53.1)	15 (62.5)	2 (25.0)	0.043
2	9 (28.1)	4 (16.7)	5 (62.5)	
3	1 (12.5)	5 (20.8)	1 (12.5)	

3.2 PRE-OPERATIVE FUNCTIONAL ASSESSMENT

Pre-operative patient reported backpain was noted in 25(78.1) patients overall reported as n(%) shown in table 2. 19 (79.2)(D) and 6(75)(DF) ($p<0.455$) reported presence of lower back pain (LBP) at time of initial assessment. This showed statistical significance. Pre-operative lower extremity symptoms were subdivided into radicular symptoms, presence of lower extremity weakness, which was further subdivided by motor grade. Radicular leg pain was present in 29 (90.6) patients overall reported as n(%) with 21(87.5) (D) and 8(100)(DF). 2(6.3)(D) patients did not have pre-operative radiculopathy ($p<1.000$). Pre-operative motor grade was obtained per lower extremity, i.e. left vs. right. These are reported as mean \pm SD. Left sided L4 was 3.9 \pm 1.6 ($p<0.896$), L5 was 3.7 \pm 1.9 ($p<0.176$) and S1 was 3.6 \pm 1.7 ($p<0.255$). Right sided L4 was 3.9 \pm 1.6 ($p<0.66$), L5 3.9 \pm 1.8 ($p<0.141$) and S1 was 3.9 \pm 1.6 ($p<0.187$). None of these were statistically significant.

Pre-operative lumbosacral paresthesia n(%) was seen in 24(75) patients with 6(18.8) patients not reporting any symptoms with a subset of patients with unknown results excluded ($p<0.645$). Final pre-operative sub-stratification based on CES type (i.e. CES-incomplete vs. CES-retention) n(%) showed 15(46.9) with incomplete and 17(53.1) with retention ($p<0.423$) with neither being statistically significant when compared between the groups.

Table 2: Pre-Operative Functional Assessment

Parameter	Overall N=32	Decompression Alone N=24	Decompression and Fusion N=8	P Value	P value with unknown excluded
Preoperative Back Pain, n (%)					0.459
Yes	25 (78.1)	19 (79.2)	6 (75.0)	0.688	
No	2 (6.3)	1 (4.2)	1 (12.5)		
Unknown	5 (15.6)	4 (16.7)	1 (12.5)		
Preoperative Leg Pain (radicular), (%)				0.576	1.000
Yes	29 (90.6)	21 (87.5)	8 (100)		
No	2 (6.3)	2 (8.3)	0 (0.0)		
Unknown	1 (3.1)	1 (4.2)	0 (0.0)		
Preoperative Motor Grade, L, Mean±SD					
L4	3.9±1.6	3.9±1.8	4.0±1.1	0.896	
L5	3.7±1.9	3.4±2.2	4.5±0.8	0.176	
S1	3.6±1.7	3.5±1.8	4.3±0.9	0.255	
Preoperative Motor Grade, R, Mean±SD					
L4	3.9±1.6	3.8±1.8	4.1±1.0	0.660	
L5	3.9±1.8	3.6±2.1	4.8±0.5	0.141	
S1	3.9±1.6	3.6±1.7	4.5±0.8	0.187	
Preoperative Lumbosacral Paresthesia, n (%)				0.641	0.645
Yes	24 (75.0)	18 (75.0)	6 (75.0)		
No	6 (18.8)	4 (16.7)	2 (35.0)		
Unknown	2 (6.3)	2 (8.3)	0 (0.0)		
Cauda Equina Syndrome Type, n (%)				0.423	
CESI	15 (46.9)	10 (41.7)	5 (62.5)		
CESR	17 (53.1)	14 (58.3)	3 (37.5)		

3.3 PRE-OPERATIVE RADIOGRAPHIC PARAMETERS

Table 3 shows affected level reported as n(%). The majority of our population selected had massive herniations at the L4/L5 level 19(59.4) with 3(9.4) at the L3/L4 level and 10(31.3) at the L5/S1. The differences between the two groups was not statistically significant ($p < 0.417$). Values are reported as mean \pm SD for our preliminary radiographic analysis. This included average disc height 7.3 ± 1.4 for the overall group, 7.6 ± 1.3 (D) and 6.6 ± 1.6 (DF) which was not statistically significant ($p < .105$). Canal diameter and disc protrusion measurements were then used to calculate a percentage of the canal that the disc occupied reported as mean \pm SD. Our overall group revealed 69.4 ± 12.9 with 71.7 ± 13.5 (D) and 61.6 ± 6.9 (DF). MRI disc grade at the affected level was analysed. Grade A was a subclass to indicate low grade disc denoting Pfirrmann grade 1, 2, or 3 and Grade B was high grade, denoting Pfirrmann grade 4 or 5. Results were noted as n(%) showing statistical significance between low and high grade discs at the affected level. Grade A discs had 24(100)(D) and 5(62.5)(DF). All grade B 1(12.5) underwent fusion ($p < 0.045$).

Table 3: Pre-operative Radiographic Parameters

Parameter	Overall N=32	Decompression Alone N=24	Decompression and Fusion N=8	P Value	P value with unknown excluded
Affected Level				0.417	
L3/4	3 (9.4)	2 (8.3)	1 (12.5)		
L4/5	19 (59.4)	13 (54.2)	6 (75.0)		
L5/S1	10 (31.3)	9 (37.5)	1 (12.5)		
Average Disk Height at Affected Level, mm, Mean±SD	7.3±1.4	7.6±1.3	6.6±1.6	0.105	
Canal Diameter Adjacent Segment Inferior, mm, Mean±SD	16.9±2.5	17.0±2.8	16.7±1.0	0.793	
Disc Protrusion Measurement, mm, Mean±SD	11.8±3.0	12.2±3.2	10.3±1.1	0.136	
Canal Diameter Disc Occupies, mm, Mean±SD	69.4±12.9	71.7±13.5	61.6±6.9	0.070	
MRI Disc Grade Affected Level, n (%)				0.007	0.045
Grade A (1,2,3)	29 (90.6)	24 (100)	5 (62.5)		
Grade B (4,5)	1 (3.1)	0 (0)	1 (12.5)		
Unknown	2(6.3)	0 (0)	2(25)		

3.4 IMMEDIATE POST-OPERATIVE FUNCTIONAL RESULTS

Table 4 shows the results from the first post-operative clinical visit either at the 6/52 or 3/12 mark. Presence of radicular leg pain was seen 9(28.1) patients overall with 7(29.2)(D) and 2(25)(DF). 14(43.8) patients reported no radicular leg pain with 10(41.7)(D) and 4(50)(DF). There were 9(28.1) unknown responses with the group comparison not yielding significant results ($p < 1.00$). Initial visit improvement in leg weakness showed complete improvement in 8(25) in the overall group, 5(20.8)(D) and 3(37.5)(DF). Partial improvement was seen in 12(37.5) overall with 8(66.7)(D) and 4(33.3)(DF). No improvement was documented in 1(3.1) overall with 1(100)(D) and 0(0) fusion. There were 11 patients with unknown improvement based on lack of documentation. None of the results were statistically significant ($p < 0.403$). Bladder bowel and sexual function showed complete resolution in 11(34.4) patients with 9(37.5)(D) and 2(25)(DF). Partial recovery was seen in 14(43.8) with 11(45.8)(D) and 3(37.5)(DF). 7(21.9) were unknown overall with statistically insignificant differences between the groups ($p < 0.635$).

Table 4 - Initial Post-Operative Functional Results

Parameter	Overall N=32	Decompression Alone N=24	Decompression and Fusion N=8	P Value	P value with unknown excluded
First Postoperative Leg Pain, n (%)					
Yes	9 (28.1)	7 (29.2)	2 (25.0)	0.919	1.000
No	14 (43.8)	10 (41.7)	4 (50.0)		
Unknown	9 (28.1)	7 (29.2)	2 (25.0)		
First Postoperative Leg Weakness Improving, n (%)					
Complete	8 (25.0)	5 (20.8)	3 (37.5)	0.403	0.755
Partial	12 (37.5)	8 (66.7)	4 (33.3)		
None	1 (3.1)	1 (100)	0 (0.0)		
Unknown	11 (34.4)	10 (90.9)	1 (0.09)		
Bladder/Bowel/Sexual Function Resolution, (n%)					
Complete	11 (34.4)	9 (37.5)	2 (25.0)	0.459	0.635
Partial	14 (43.8)	11 (45.8)	3 (37.5)		
None	0 (0)	0 (0)	0 (0)		
Unknown	7 (21.9)	4 (16.7)	3 (37.5)		

3.5 LONG TERM FOLLOW UP BASELINE DEMOGRAPHIC DATA

Overall group post LTFP yielded a sample size of 12 patients. All patients interviewed were in the decompression alone group. Table 5 shows baseline characteristics represented as frequencies denoted n(%). 6(50) were married, 6(50) single. 9(75) of patients were non-smokers and 3(25) were smokers. 4(33.3) patients were not working with 8(66.7) patients currently employed. Education status was obtained showing 1(8.3) with elementary level education, 2(16.7) with high school education, and 9(75) with college or post-graduate education. BMI was 30.5 ± 6.85 (mean \pm SD).

Table 5 - Long-Term Demographic Results

Parameter	Frequency	Percent
Marital Status (Single, Married)		
Married	6	50
Single	6	50
Total	12	100
Smoking Status		
No	9	75
Yes	3	25
Total	12	100
Work Status (Working, Not Working)		
Not Working	4	33.3
Working	8	66.7
Total	12	100
Education Status (Elementary, Highschool, College, Post Grad)		
Elementary	1	8.3

High School	2	16.7
College/PostGrad	9	75
Total	12	100

3.6 LONG TERM FOLLOW UP PATIENT REPORTED OUTCOME MEASURES

Numerical rating scales for back pain, leg pain, and leg paresthesias are seen in Table 6. Findings are reported as mean±SD. Overall group back pain was 3.83±3.56. Leg pain was 3.33±3.75 and paresthesia was 5.08±3.18. ODI was reported as a score out of 50. Range of score was 0-37 with a mean±SD of 14.83±11.81. SF-12 was divided into physical and mental component scores (PCS and MCS). PCS ranged from 21.74-57.34 with a mean of 36.67±11.76 (mean±SD)

3.7 LONG TERM FOLLOW UP CLINICAL EXAMINATION FINDINGS

MRC grading for lower extremity motor exams and sensory exam results yielded the following results reported as mean±SD. Left sided lower extremity examination showed 4.58±1.44, 4.5±1.45 and 4.58±1.17 for L4, L5, and S1 respectively. Sensory exams showed 1.83±0.58 for both L4 and L5 and 1.58±0.79 for S1. Right sided lower extremity examination showed 3.83±2.13, 3.75±2.26 and 4.08±1.93 for L4, L5 and S1 respectively. Sensory exams yielded 1.67±0.492 for L4 and L5 and 1.50±0.67 for S1. (Table 6) FIM instrument tool results looking at bladder and bowel management revealed 5(41.7) for complete recovery and 7(58.3) partial recovery reported as n(%). (Table 7)

3.8 LONG TERM FOLLOW UP RADIOGRAPHIC AND REOPERATION

Post-operative standing lumbar radiographs were analysed to determine presence of instability defined as spondylolisthesis at the affected level, recurrence of disc herniation, average disc height at the operative level, and absolute number of re-operations. 2(16.7) has post-decompression spondylolisthesis, 2(16.7) had recurrence of disc herniation at the initial operative level and 2(16.7) underwent re-operation (n(%)). The average disc height at the affected level was 5.8mm. (Table 8)

Table 6 - Long Term Follow Up Clinical and Patient Rated Outcomes

Parameter	Number of Patients	Minimum	Maximum	Mean	Standard Deviation
SF-12 PCS	12	21.74	57.34	36.6617	11.76027
SF-12 MCS	12	19.36	62.33	46.5417	14.15122
NRS Back	12	0	10	3.83	3.563
NRS Leg	12	0	10	3.33	3.75
NRS Paresthesia	12	0	10	5.08	3.175
ODI (score out of 50)	12	0	37	14.83	11.808
LTFP Motor Grade L4 L	12	0	5	4.58	1.443
LTFP Motor Grade L5 L	12	0	5	4.5	1.446
LTFP Motor Grade S1 L	12	1	5	4.58	1.165
LTFP Motor Grade L4 R	12	0	5	3.83	2.125
LTFP Motor Grade L5 R	12	0	5	3.75	2.261
LTFP Motor Grade S1 R	12	0	5	4.08	1.929
LTFP Sensory Grade L4 L	12	0	2	1.83	0.577
LTFP Sensory Grade L5 L	12	0	2	1.83	0.577
LTFP Sensory Grade S1 L	12	0	2	1.58	0.793
LTFP Sensory Grade L4 R	12	1	2	1.67	0.492
LTFP Sensory Grade L5 R	12	1	2	1.67	0.492

LTFP Sensory Grade S1 R	12	0	2	1.5	0.674
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Table 7 - Long Term Lower Sacral Symptom Resolution

Parameter	Frequency	Percent
complete	5	41.7
partial	7	58.3
Total	12	100

Table 8 – Long Term Radiographic and Re-Operation Parameters

Parameter	Total n=12
Instability (Spondylolisthesis) n(%)	2(16.7)
Recurrence of Disk Herniation n(%)	2(16.7)
Average Disk Height at Operative Level (mm)	5.8
Re-Operation n(%)	2(16.7)

4. DISCUSSION

This chapter will outline a summary of the study results and a discussion surrounding them, as well as provide an overview of study limitations and potential future directions for clinical research.

4.1 SUMMARY AND DISCUSSION

Posterior spinal surgery through either a decompression or additional fusion procedure is the widely accepted standard of care for patients presenting with CES secondary to massive disc herniation. A plethora of literature has been published regarding post-surgical outcome, particularly in regards to improvement of lower sacral symptoms in relation to timing of surgery. These outcomes are usually classified based on the severity of the initial presentation with incomplete presentations usually having better long-term outcomes in comparison to the retention subtype of the process. Advantages of surgery are to alleviate the compression, improve lower back pain (LBP) and lower sacral symptoms. It is hypothesized that lumbar fusion surgery potentially can improve LBP in the long term due to the immobilization of the segment with instrumentation. However, increased operative time, cost, and adjacent segment disease are potential downsides. With the decompression alone group, there is a theoretical risk of recurrence if there was inadequate decompression or recurrence of herniation. This study hypothesized that there would be no difference in long term patient reported outcome measures between patients undergoing decompression or decompression and fusion for a clinical and radiographic diagnosis of cauda equina syndrome.

Our initial retrospective analysis showed statistical significance in baseline demographic data, the decompression group in our study had a significantly higher BMI at 33.1 ± 6.8 compared to the fusion group which showed a BMI of 25.6 ± 4.3 ($p < 0.033$). This could potentially be related to our fusion cohort being deconditioned due to functional limitation but also age; they were close to 10 years older on average. When looking at our cohort overall however, average BMI was noted at 31.2 ± 7 . The findings were consistent with the literature surrounding adult lumbar disc herniation in the general population.¹³ The decompression group in our study had a significantly higher BMI

at 33.1 ± 6.8 compared to the fusion group which showed a BMI of 25.6 ± 4.3 . Interestingly, operating surgeon showed significance with one surgeon conducting significantly higher proportions of fusions in comparison to decompressions. This could be explained by patient selection or have introduced surgeon bias. Furthermore, pre-operative functional characteristics appeared to have no statistically significant difference between the two groups in both motor examinations in the lower extremities, along with lower sacral symptoms and cauda equina syndrome subtype (i.e. CES-I vs CES-R). This is certainly something that would be expected as both groups usually present with a similar constellation of symptoms due to the pathophysiology of the condition.

However, when looking at the radiographic analysis of the pre-operative MRIs, it was clear that there was a delineation between those in the decompression vs. the fusion group, particularly when looking at the MRI disc Pfirrmann grade. All of the high-grade discs that were seen in the study, i.e. Grade 4 or 5 underwent fusion procedures with the majority of the lower grade discs undergoing decompression alone. This trend correlates clinically with the extent of surgical decompression and potential for creating instability when removing either a large or degenerative disc, hence necessitating a fusion procedure.

Our long-term follow up included 12 patients, with the remainder of the patients unreachable or unwilling to participate. NRS back, leg, and paresthesia questionnaires along with ODI and SF-12 was administered by a single physician with clinical examination performed. A study looking at long-term outcomes after CES and factors affecting them conducted by McCarthy et al showed a mean ODI of 29 and pain score of 4.5. These figures appear somewhat higher than our data with our mean ODI level being 14.83 ± 11.8 and NRS for back pain lower than their group 3.83 ± 3.6 . This difference is potentially related to confounding patient factors and potentially variations in post-operative rehabilitation protocols. Interestingly, Fairbank et al. published showing mean weighted ODI in normal populations of 10.19 ± 2.2 and 27 ± 5.8 for those with primary lower back pain. Our cohort therefore shares similarities to those with a primary lower back pain complaint, which would be consistent with the overall disease presentation of significant lower back pain.

23,24

Hopman et al. looked at SF-36 results for the general Canadian population and subdivided those based on age and sex. When looking at the combined population however for ages 25-34, PCS was 53 ± 7.2 and MCS 50.1 ± 9.6 . When looking at the next age cohort 35-44, PCS was 52 ± 8.0 and MCS 50.9 ± 9 . These cover our age ranges in our population. Though we used the SF-12 questionnaires, there is transferability between the results. Our cohort showed PCS 36.6 ± 11.7 and 46.54 ± 14.15 . Certainly compared to the general population there is persistent disability in our cohort post-operatively long term.²⁵

With regards to lower sacral symptoms, there was complete resolution of symptoms in 41.7% of patients within the decompression group with partial resolution in the remainder of the group. A study by Siedel et al. looked at CES lower sacral symptom recovery in comparison to non-CES controls undergoing decompression surgery, which showed that CES was an independent predictor of persistent bladder dysfunction. Interestingly, they found there was a higher risk of urologic surgery as sequelae as well due to the persistent dysfunction. This was not seen in our patient cohort. A study by Kumar et al. looking at CES post-surgical outcomes due to decompression through meta-analysis showed a 43.3% (range 29.1-57.5) rate of persistent bladder dysfunction, which does correlate with our findings.^{26,27}

When looking at the long-term functional outcome in terms of motor grade recovery, there is certainly a positive trend noted within the decompression group with improvement in L4, L5, and S1 motor grades noted consistently on L sided examination to at least 1 motor grade higher and equal or slightly improved motor grades on the R side. This difference between sides is potentially due to the initial neurological insult preferentially affecting the R sided roots over the left but may be biased based on interobserver variability given the fact that the retrospective exams unlike our prospective cohort were performed by varying examiners. Dhatt et al. performed an analysis of a case series of 50 patients with late presentations which showed 39 patients having full motor recovery and 6 with partial recovery with the mean duration of recovery quoted as 13.5 months. We can thereby correlate that to our data and infer that our patients likely had the same trajectory for recovery however our population may not be consistent given variations in the timing of surgery as their population was consistently late presentations.²⁸

Review of our post-operative radiographs and surgical records showed 2 patients within our decompression group had developed a post-decompression spondylolisthesis, 2 patients had recurrence of their disc herniation and 2 patients underwent re-operation for repeat symptom presentations, both being secondary to recurrent massive disc herniation causing cauda equina symptoms. A review by Mariscal et al. showed that the incidence of recurrent disc herniation in patients having undergone lumbar discectomy ranges from 0% to as high as 15%.²⁹ Certainly our cohort of recurrent herniation at the affected level was 16.7%, which is quite close to the quoted literature, with the discrepancy likely related to our low sample size. Interestingly, our patients with the post-decompression spondylolisthesis did not undergo reoperation even though they had radiographic evidence of instability. Ramhmdani et al. showed that the rate of post-laminectomy spondylolisthesis, caused likely by iatrogenic injury at the time of decompression ranged, and requiring fusion, ranged from 1.6%-32%. They predicted that higher risk subsets were those undergoing multi-level decompressions along with violation of the posterior facet structures were factors that had a large influence on spinal motion parameters and thereby, instability.³⁰ Our cohort underwent single level laminectomies, which are potentially lower risk, and it is possible that our cohort had an aspect of degenerative spondylolisthesis in conjunction with the post-laminectomy spondylolisthesis, and have not experienced any symptoms necessitating intervention; longer term follow up may show the need for a fusion procedure.

4.2 LIMITATIONS AND FUTURE DIRECTIONS

The goal of this thesis was to understand if there were any long-term patient reported outcome differences between those undergoing decompression and those with an additional posterior fusion procedure for a diagnosis of CES. However, there were several limitations that were both inherent to the nature of the study, and the nature of the follow-up. These are outlined below.

With regards to sample size, this was a clear limitation from both a retrospective and prospective lens. Over 2400 patient charts were reviewed with less than 35 patients being selected for our initial retrospective analysis. In addition to this, there was difficulty in obtaining data from charts given not only lack of health record due to paper chart and electronic cross over, but significant variation with regards to charting, leading to inter-observer bias that was seen. This in turn further depleted the total number of patients included in the statistical analysis and thereby, could have potentially lead to lack of statistical significance wherein there may have been some. This was confounded by the rarity of the disease process being studied overall, which further limits our attempts to increase our sample size; our sample did have concordance however with other published studies. With this said, national database data may help going forward in order to have multi-centre information hopefully yielding more appropriate results and equal cohorts between both the groups.

Next, the patient interview recruitment process itself yielded significant challenge. Patients were initially selected between the years 2005-2015 to facilitate a longer-term follow-up. As such, certain patients may have moved with no new demographic information available. Multiple attempts to contact these patients through various routes in accordance with our ethics were attempted to no avail. Unfortunately, this in turn led to a lack of patients being cohorted from the fusion group who initially had a significantly lower proportion of patients from our overall group. This could potentially be due to the fusion group having improved back pain and functional outcomes in comparison to the decompression group and hence did not feel the need for repeat follow up. These patients also did not reach out for post-fusion follow up, which could potentially allow us to infer that they have not had symptom recurrence or adjacent segment difficulties, which are known complications of the procedure. All in all however, we were unable to obtain long term

follow up information from the fusion group patient in order to adequately address our initial study question; the data that was collected retrospectively from the decompression and fusion groups showed no significant difference in early post-operative patient rated outcome measures (PROMS).

4.3 CONCLUSION

CES secondary to massive disc herniation is a definite indication for posterior lumbar surgery. Our study sought to identify long term clinical differences between a cohort of patients undergoing decompression alone to those undergoing decompression and an additional fusion procedure. Our initial post-operative data showed that there was no significant difference between early post-operative PROMs between the two groups. Our long-term data, given limitation, showed data for the decompression cohort alone, and as such, only trends could be ascertained. Certainly there appears to be a general improvement in lower extremity motor grade and return of lower sacral symptoms compared to the pre-operative levels, but the initial hypothesis question remains unanswered. As such, further clinical study with a multicentre prospective approach would help illuminate this topic further.

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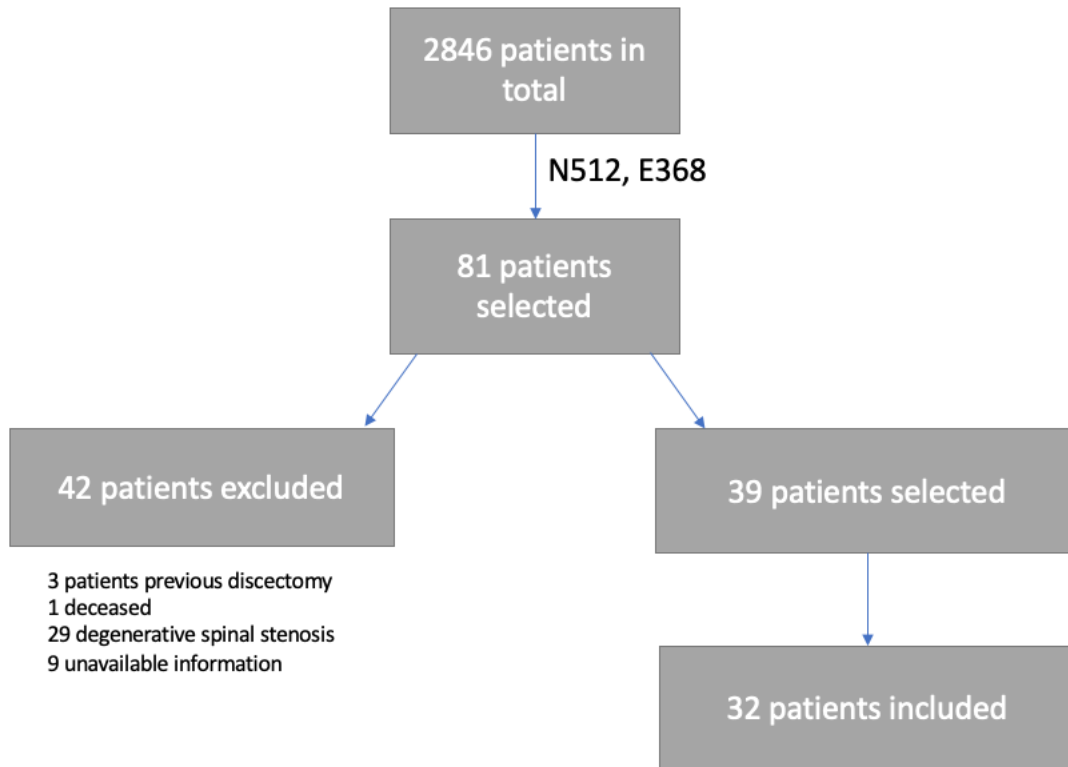
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APPENDICES:

A) Flowchart of Patient Selection



B) Oswestry Disability Index Questionnaire

OSWESTRY QUESTIONNAIRE Participant ID#: _____

INSTRUCTIONS: This questionnaire has been designed to give us information as to how your back or leg pain affect your ability to manage in everyday life. Please answer every section and mark in each section **ONLY ONE BOX** which applies to you. We realize you may consider that two of the statements in any one section relates to you. PLEASE REMEMBER JUST MARK ONE BOX WHICH MOST CLEARLY DESCRIBES YOUR PROBLEM.

Section 1 - Pain Intensity (*check only one*)

- I have no pain at this moment
- The pain is very mild at the moment
- The pain is moderate at the moment
- The pain is fairly severe at the moment
- The pain is very severe at the moment
- The pain is the worst imaginable at the moment

Section 2 - Personal Care (*check only one*)

- I can look after myself without causing extra pain
- I can look after myself normally, but it is very painful
- It is painful to look after myself and I am slow and careful
- I need some help but manage most of my personal care
- I need help every day in most aspects of my personal care
- I do not get dressed, wash with difficulty and stay in bed

Section 3 - Lifting (*check only one*)

- I can lift heavy weights without extra pain
- I can lift heavy weights but it gives extra pain
- Pain prevents me from lifting heavy weights off the floor but I can manage if they are conveniently positioned
- Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned (eg on a table)
- I can lift only very light weights
- I cannot lift or carry anything at all

Section 4 - Walking (*check only one*)

- Pain does not prevent me walking any distance
- Pain prevents me from walking more than 1 mile
- Pain prevents me from walking more than ¼ mile
- Pain prevents me from walking more than 100 yards
- I can only walk using a stick or crutches
- I am in bed most of the time and have to crawl to the toilet

Section 5 - Sitting (*check only one*)

- I can sit in any chair as long as I like
- I can sit in my favorite chair as long as I like
- Pain prevents me from sitting more than 1 hour
- Pain prevents me from sitting more than ½ hour
- Pain prevents me from sitting more than 10 minutes
- Pain prevents me from sitting at all

Section 6 - Standing (*check only one*)

- I can stand as long as I want to without extra pain
- I can stand as long as I want, but it gives me extra pain
- Pain prevents me from standing more than 1 hour
- Pain prevents me from standing more than ½ hour
- Pain prevents me from standing for more than 10 minutes
- Pain prevents me from standing at all

Section 7 - Sleeping (*check only one*)

- My sleep is never disturbed by pain
- My sleep is occasionally disturbed by pain
- Because of pain, I have less than 6 hours sleep
- Because of pain, I have less than 4 hours sleep
- Because of pain, I have less than 2 hours sleep
- Pain prevents me from sleeping at all

Section 8 - Sex Life (*check only one*)

- My sex life is normal and causes no extra pain
- My sex life is normal but causes some extra pain
- My sex life is nearly normal but it is very painful
- My sex life is severely restricted by pain
- My sex life is nearly absent because of pain
- Pain prevents any sex life at all

Section 9 - Social Life (*check only one*)

- My social life is normal and causes me no extra pain
- My social life is normal but increases the degree of pain
- Pain has no significant effect on my life apart from limiting my more energetic interests (eg sports)
- Pain has restricted my social life and I do not go out as often
- Pain has restricted my social life to home
- I have no social life because of pain

Section 10 - Traveling (*check only one*)

- I can travel anywhere without extra pain
- I can travel anywhere but it gives extra pain
- Pain is bad, but I manage journeys over 2 hours
- Pain restricts me to journeys of less than 1 hour
- Pain restricts me to short necessary journeys under 30 minutes
- Pain prevents me from traveling except to receive treatment

Thank you for completing these questions!

C) Numerical Rating Scale Tool

A) On a scale from 0 to 10, mark your OVERALL level of BACK pain:

No pain

Unbearable pain

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
0	1	2	3	4	5	6	7	8	9	10

B) On a scale from 0 to 10, mark your OVERALL level of LEG pain:

No pain

Unbearable pain

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
0	1	2	3	4	5	6	7	8	9	10

c) On a scale from 0 to 10, mark your OVERALL level of LEG tingling/burning/numbness:

No abnormal feelings

Unbearable abnormal feelings

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
0	1	2	3	4	5	6	7	8	9	10

D) SF-12 Questionnaire

The following questions ask for your views about your GENERAL HEALTH. Please answer each question with consideration to your OVERALL health at this point in time, not only in regard to the reason for this visit. Please answer every question. Some questions may look like others, but each one is different. Please take the time to read and answer each question carefully, and select the one choice per question that best describes your answer.

SF1. In general, would you say your health is:

- Excellent
- Very Good
- Good
- Fair
- Poor

SF2. The following questions are about activities you might do during a typical day. Does your health now limit you in the activities below? If so, how much?

Moderate activities, like moving a table, pushing a vacuum cleaner, bowling or playing golf:

- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

Climbing several flights of stairs:

- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

SF3. During the past 4 weeks, how often have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

Accomplished less than you would like:

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

Were limited in the kind of work or other activities:

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

SF4. During the past 4 weeks, how often have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

Accomplished less than you would like:

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

Did work or activities less carefully than usual:

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

SF5. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

- Not at all
- A little bit
- Moderately
- Quite a bit
- Extremely

SF6. These questions are about how you have been feeling during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks:

Have you felt calm and peaceful?

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

Have you had a lot of energy?

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

Have you felt downhearted and depressed?

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

SF7. During the past 4 weeks, how much of the time has physical health or emotional problems interfered with your social activities (visiting friends, relatives, etc.)?

- All the time
- Most of the time
- Some of the time
- A little of the time
- None of the time

E) FIM Instrument

FIM™ Instrument

L E V E L S	7 Complete Independence (Timely, Safely)	NO HELPER		
	6 Modified Independence			
	Modified Dependence			
	5 Supervision (Subject = 100%+)			
	4 Minimal Assist (Subject = 75%+)			
	3 Moderate Assist (Subject = 50%+)	HELPER		
	Complete Dependence			
	2 Maximal Assist (Subject = 25%+)			
	1 Total Assist (Subject = less than 25%)			

	ADMISSION	DISCHARGE	FOLLOW-UP
Self-Care			
A. Eating	<input type="text"/>	<input type="text"/>	<input type="text"/>
B. Grooming	<input type="text"/>	<input type="text"/>	<input type="text"/>
C. Bathing	<input type="text"/>	<input type="text"/>	<input type="text"/>
D. Dressing - Upper Body	<input type="text"/>	<input type="text"/>	<input type="text"/>
E. Dressing - Lower Body	<input type="text"/>	<input type="text"/>	<input type="text"/>
F. Toileting	<input type="text"/>	<input type="text"/>	<input type="text"/>
Sphincter Control			
G. Bladder Management	<input type="text"/>	<input type="text"/>	<input type="text"/>
H. Bowel Management	<input type="text"/>	<input type="text"/>	<input type="text"/>
Transfers			
I. Bed, Chair, Wheelchair	<input type="text"/>	<input type="text"/>	<input type="text"/>
J. Toilet	<input type="text"/>	<input type="text"/>	<input type="text"/>
K. Tub, Shower	<input type="text"/>	<input type="text"/>	<input type="text"/>
Locomotion			
L. Walk/Wheelchair	<input type="text"/>	<input type="text"/>	<input type="text"/>
M. Stairs	<input type="text"/>	<input type="text"/>	<input type="text"/>
	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: small;"> W Walk C Wheelchair B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: small;"> W Walk C Wheelchair B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: small;"> W Walk C Wheelchair B Both </div>
Motor Subtotal Score	<input type="text"/>	<input type="text"/>	<input type="text"/>
Communication			
N. Comprehension	<input type="text"/>	<input type="text"/>	<input type="text"/>
O. Expression	<input type="text"/>	<input type="text"/>	<input type="text"/>
	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> A Auditory V Visual B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> A Auditory V Visual B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> A Auditory V Visual B Both </div>
	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> V Vocal N Nonvocal B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> V Vocal N Nonvocal B Both </div>	<input type="text"/> <div style="display: flex; justify-content: space-around; font-size: x-small;"> V Vocal N Nonvocal B Both </div>
Social Cognition			
P. Social Interaction	<input type="text"/>	<input type="text"/>	<input type="text"/>
Q. Problem Solving	<input type="text"/>	<input type="text"/>	<input type="text"/>
R. Memory	<input type="text"/>	<input type="text"/>	<input type="text"/>
Cognitive Subtotal Score	<input type="text"/>	<input type="text"/>	<input type="text"/>
TOTAL FIM Score	<input type="text"/>	<input type="text"/>	<input type="text"/>

NOTE: Leave no blanks: enter 1 if patient not testable due to risk.

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2) *“Comparing outcomes in fusion surgery between back pain dominant and leg pain dominant patient primary complaints for Adult Isthmic Spondylolisthesis. A CSORN ambispective study”* Algnamoosh N, **Raj R**, Urquhart J, Bailey C.
London Health Sciences Center, Lawson Research **Global Spine Journal**