PREDICTING HEALTH CARE NEEDS FOLLOWING LUMBAR SPINE SURGERY

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Abstract

Low back pain is one of the most common health problems globally, having significant impact on individuals, community, and health care system. Lumbar Spine Surgery (LSS) is usually considered a treatment of low back pain when conservative management fails. In the United States, there has been an increase in the prevalence of LSS, with a similar increase in surgery costs and related post-surgical care. Although LSS is often considered to be a more efficient treatment than the nonsurgical management, the improvements gained from LSS are not optimal, resulting in no change or even worsening of symptoms in some cases. Investigating and understanding variables associated with surgical outcomes would be cost effective and clinically significance. Limited studies have attempted to examine patient recovery in acute state following LSS. Specifically, studies are lacking to identify predictors of length of hospital stay (LOS), discharge placement (DP), and outcomes as early as 2 weeks post-discharge after having LSS. Bridging the gap in knowledge related to predictors of short-term LSS outcomes is the goal of this work. Identifying these predictors may lead to better utilization of resources, improvement of patient care, and optimization of LSS outcomes.

Chapter 2 sought to identify predictors of LOS using various potential surgical and non-surgical variables. We used structural equation modeling analysis to study the direct effect of three latent factors on LOS: presurgical, surgical, and postsurgical factors. The three latent factors were constructed from potential predictor variables (indicators) that had significant direct effect on their related factors. Results showed that higher age, diminished prior level of function, needing assistive devices, and low presurgical hemoglobin level were significant indicators of presurgical factors and associated with longer LOS. Secondly, high illness severity, increased complications, and need for intensive care unit stay after surgery were significant indicators of

surgical factors and associated with higher LOS. Finally, inpatient physical therapy assessment, including low sitting and standing balance score, higher dependency in bed mobility transfer and mobility, and less distance walked during physical therapy sessions, were significant indicators of postsurgical factors and associated with longer LOS. The model explained 47% of the variation in LOS. Postsurgical factors constructed from physical therapy assessment explained the highest percentage of the variation in LOS, followed by surgical factors, and finally presurgical factors that individually explained minor percentage of variation in LOS. Prospective studies are needed to confirm these results, and should consider including standardized clinical testing, especially at baseline to improve the prediction accuracy.

Given that discharge placement (DP) predictors has been studies after many surgeries and conditions including total knee, total hip replacement, stroke and brain injury, little is known regarding the predictors of DP following LSS. Chapter 3 sought to address this gap in knowledge. Results showed that younger age, longer distance walked during hospital stay, and shorter length of hospital stay predicted greater likelihood of being discharged to home. Further analysis suggested that those living along, have inferior level of function prior to their surgery, and required longer hospital stay are likely to need skilled assistance (i.e. home health care or outpatient services) after being discharged to home. Prospective studies with more potential variables as predictors should be conducted to confirm these results.

Short-and long-term outcomes following LSS were studied extensively following LSS. However, to our knowledge no study has investigated surgery outcomes earlier than 6 weeks post-hospital discharge. Therefore, chapter 4 explored the changes in patients' clinical status at 2 weeks following hospital discharge, and predictors of patient- outcomes during this short follow-up period. Results revealed that patients had significant reduction in back pain intensity, leg pain

intensity, and improvement in function. However, there was no significant change in the type of analgesics used. High somatic perception predicted higher back pain, poor function, and inferior quality of life. Longer symptom duration was associated with higher postoperative back pain intensity, while diagnosis of spondylolisthesis and preoperative use of opioids predicted higher postoperative leg pain intensity. Having high functional level at baseline was associated with high functional level postoperatively. Experiencing higher back and leg pain intensity, having depression symptoms, smoking, and receiving worker's compensation were significant factors associated with negative patient-perception of surgery outcomes. The study showed that multiple variables should be considered when predicting short-term LSS outcomes.

In summary this dissertation work presented that LSS is effective in management of patients' pain, and improving function and quality of life for short-term follow up. Multiple variables showed to predict LOS, DP, and surgery outcomes after 2 weeks of post discharge after LSS. These variables could be presurgical variables including sociodemographic variables, cognitive behavioral variables, presurgical clinical status, presurgical functional level, or surgical including severity of illness, complications, longer intensive care unit and total hospital LOS, and postsurgical which including physical therapy functional assessment measures. The new knowledge presented in this work is important in guiding patients' selection criteria, establishing realistic expectations from surgery, and designing strategies to optimize surgery outcomes. Prospective studies with larger sample are needed to fully understand determinant of LSS success.

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Chapter 1

Introduction

1.1 Low back pain: Prevalence and health care costs

All over the world, Low Back Pain (LBP) is one of the most common health problems, with significant impact on individuals, community, and health care costs.(Dionne, Dunn, & Croft, 2006; Rapoport, Jacobs, Bell, & Klarenbach, 2004) Globally, it is estimated that point prevalence of LBP is 11.9%, and one-month prevalence is 23.2%.(Hoy et al., 2012) LBP is a leading cause of disability in the United States (US), contributing to temporary disability in 3-4% of the population and permanent disability in 1% of the working population.(Manek & MacGregor, 2005; Ricci et al., 2006) An estimate of 50-85% of the population has reported experiencing LBP at least once in their lifetime.(Stewart, Ricci, Chee, Morganstein, & Lipton, 2003) LBP is more common among the elderly population, the female population, and individuals of American Indian, Alaskan Indian, and European descent.(Hoy, et al., 2012; Schiller, Lucas, Ward, & Peregoy, 2012) The prevalence of LBP increased dramatically from 1992 to 2006 by 162%, with a 219% increase in the 45-54 age group, with a slightly higher increase in males than females (176% versus 154%), and a noticeably higher increase in non-Hispanic black (226% in comparison to 155% non-Hispanic white).(Schiller, et al., 2012)

LBP is an activity-limiting pain in the lower region of the back with or without leg pain that last more than one day.(Hoy et al., 2010) While 95% of LBP cases are resolved within 3 months of occurrence, 5% develop into chronic LBP resulting in substantial healthcare cost. (Wier et al., 2009) The cost of LBP management and resultant disability in the US is continuously increasing. LBP ranks fifth among the foremost reasons for visiting physicians, (Porchet et al., 2009) and Americans spend at least $23 billion annually on LBP related health care costs. (Cenic & Kachur, 2009; Luo, Pietrobon, Sun, Liu, & Hey, 2004) Approximately $50 billion is spent annually on the management of LBP, with approximately one third attributed to

the surgical management for LBP.(Chou et al., 2009; Martin et al., 2009) In a systematic review

of estimated costs of LBP management on the international level (including the US), physical

therapy (PT) management and inpatient services costs were estimated to be the highest among

other management costs, with each contributing to 17% of total LBP costs as compared to 5%

for surgery costs, 13% for pharmaceutical expenses and 8% for outpatient services.(Dagenais,

Caro, & Haldeman, 2008) Loss of productivity and missed working days are also indirect costs

for LBP, estimated to account for around 52% of total LBP costs. (Becker et al., 2010) With such

staggering figures, an increased socioeconomic burden of managing people with LBP, and a

large body of research on the medical and clinical management of LBP, there is a need to

evaluate the effectiveness and outcomes of common LBP management strategies for the aim of

improving clinical outcomes and reducing health care costs.

1.2 Therapeutic procedures and surgical management

There is a classic treatment course for LBP. Conservative management is recommended

for acute LBP (<3 months of onset) with no serious neurological manifestation, and include bed

rest, non-steroidal anti-inflammatory medications, corticosteroids injections, and analgesics as

necessary. (Katz et al., 1997) Various physical agents such as electrotherapy and thermotherapy

could be used to treat the condition. Physical therapists educate patients about proper body

mechanics that alleviate pain and activities to be avoided. PT management is tailored to meet the

individual needs of the patients, including appropriate prescription of intensity and duration of

exercises. A surgical intervention is usually prescribed as a second line of treatment for LBP

management, when either extensive conservative management fails to meet therapeutic aims

and/or the patient experiences neurological deficits, or progressive and worsening symptoms.

(Cloyd, Acosta, & Ames, 2008) At times, surgery is performed on urgent bases when "red flags" such as serious neurological deficits or segmental instability are identified. (Dawson & Bernbeck, 1998) However, spinal surgeries are also performed with less serious symptoms as described below.

1.2.1 Lumbar spine surgery

The prevalence of lumbar spine surgeries (LSS) in the US is approximately 0.2% of the population, (Gray et al., 2006) at least 40% higher than in any other country in the world, and five times higher than in England and Scotland.(Cherkin, Deyo, Loeser, Bush, & Waddell, 1994; Ostelo et al., 2003) The rate of inpatient- and outpatient-based LSS rose by 37/100,000 between 1994 and 2000.(Gray, et al., 2006) Surgery has an impact on individuals economic status; subjects who underwent spine surgery experienced $2,884 loss of wages after one year of surgery, yet had higher employment rate 3 years after surgery in comparison to preoperative status.(Fayssoux, Goldfarb, Vaccaro, & Harrop, 2010)

Lumbar spinal stenosis is the most common reason for spinal surgery.(Deyo, 2005) Spinal stenosis is a narrowing of the central vertebral canal or lateral foramina affecting one or multiple levels of lumbar vertebra/e, either one side or both sides of spinal foramina respectively. (Clarke & Rosen, 2001) It is mainly caused by degeneration and bulging of the intervertebral disc, facet joints hypertrophy, and ligamentum flavum thickening.(Allen et al., 2009; Cloyd, et al., 2008) These conditions cause compression on the dural sac and nerve roots,(Cloyd, et al., 2008) resulting in LBP and radiating pain into lower extremities in form of aching, numbness, and tingling, and could progress to neural and motor deficits such as bladder and bowel

dysfunction, sensory impairments, muscle weakness, or abnormal deep tendon reflexes.(Cloyd, et al., 2008)

Lumbar disc herniation, prolapse, protrusion, or extrusion account for less than 5% of all low back problems, but are one of the most common causes of nerve root pain and surgical interventions.(Manchikanti, Derby, Benyamin, Helm, & Hirsch, 2009) The abnormal disc (e.g. herniated could cause compression of neural tissues. Degeneration of discs occurs with increasing age and could lead to non-radicular pain which may also require surgical intervention. (Allen, et al., 2009)

Spondylolisthesis, defined as the anterior shifting of one vertebra in comparison to adjacent vertebrae, is another condition that may require surgery if the displacement could not be corrected with conservative approaches and neural compression is manifested. Further indications for spinal surgeries would be spinal tumor, spinal infection, spinal fracture and other conditions which are beyond the scope of our current project.

1.2.2 Types of lumbar spine surgeries

Discectomy, laminectomy, and spinal fusion are common surgical procedures for LBP treatment.(Chou, et al., 2009) Discectomy is the surgical removal of disc material that compresses a nerve root and is the least invasive of all three surgeries. This surgery has a short-term benefit, with no clear evidence for long-term benefit. (O'Connell, Malhotra, Vresilovic, & Elliott, 2011) Discectomy has a success rate of at least 75%, as suggested by self-reported patient outcomes.(Asch et al., 2002)

Laminectomy (or open decompression surgery) is a common spinal surgery used to relieve neuro-compression symptoms in LBP by the resection of the lamina and other parts of the

vertebra.(Lee et al., 2010) When only part of the lamina is removed, the surgery is known as Laminotomy. This procedure may predispose the spine to instability overtime.(Lee, et al., 2010) Sometimes it is followed by fusion to enhance stability of the excised segment.(Katz, et al., 1997) In 2004, approximately 242,000 laminectomy procedures were done in the US, with hospital charges (excluding physician fees) of $5 billion.(Deyo, 2007)

Fusion (or arthrodesis) surgery is performed to alleviate pain resulting from unstable or increased segmental motion by replacing a motion segment (two vertebral bodies and a disc in between) with solid arthrodesis.(Deyo, 2007; Djurasovic et al., 2011) Bony grafts are typically taken from the iliac crest and placed between the transverse processes of two adjacent vertebrae on posterior elements of the spine. In addition to bone grafting, screws and plates are used to fasten the motion segment.(Deyo, 2007) Fusion is indicated to decrease pain with movement and/or correct abnormal structural deformity, to enhance stability, and /or prevent progressive deformity (e.g. Spondylolisthesis).(Deyo, 2007; Deyo, Nachemson, & Mirza, 2004; Katz, et al., 1997) The procedure may also be performed to stabilize spine segmental instability due to laminectomy or discectomy.(Deyo, et al., 2004) The rate of this surgical procedure has increased in the last decade,(Djurasovic, et al., 2011) Between 1996 and 2001, the annual rate of spinal fusion rose more than five times than the rate of hip and knee arthroplasty in the US.(Wier, et al., 2009) Yet the clinical outcomes continue to vary.(Glassman et al., 2009) The estimated hospital charges (without physicians fees) for this surgery was more than $16 billion for 300,000 operations conducted in 2004 in the US.(Deyo, 2007)

In the current project, we aim to study predictor of the outcomes in the three different surgeries: we will study predictors of length of hospital stay (LOS) after fusion and laminectomy (chapter 2), discharge placement (DP) after laminectomy (and laminotomy) (chapter 3), and

various health care outcomes following 2 weeks of discectomy, laminectomy, and fusion (chapter 4).

1.2.3 Definition of lumbar spine surgery success and measurement

The classical definition of surgery success depends on imaging, surgery technical results (e.g. union of fusion surgery), and objective physiological and functional measures.(Mannion, Junge, et al., 2009) The success rates of surgery vary, and some patients continue to have symptoms such as pain, functional limitations, and motor deficits.(Ostelo, et al., 2003) Patients following any spinal surgeries may continue to experience various signs and symptoms with no definite evidence or determining factors that could predict the outcomes of these surgeries and the extent of health care needed for these patients.

Patient usually needs immediate assistance following the surgery from nursing and physical therapy staff. The amount of care needed following a surgery could be measured by the LOS. LOS could also reflect the immediate recovery following the surgery. The success rates after LSS for pain reduction and improvement in functional ability and general health are inconsistent. Upon discharge from the hospital, the patient may need continuous community care depending on his recovery and the type of community care available for the patient. In the retrospective part of this project, we studied the predictors of LOS, and discharge placement (DP) (chapter 2, and 3).

Many measures are used to determine outcomes of LSS. The most frequently used outcome measures include assistance needed following hospital discharge, pain, function/disability, need for revision, return to work, quality of life, and patient-perceived effects. (den Boer et al., 2006; Mannion, Denzler, Dvorak, & Grob, 2010; Mannion & Elfering,

2006; Mannion et al., 2007; Mannion, Junge, et al., 2009; Trief, Ploutz-Snyder, & Fredrickson, 2006; Zheng, Cammisa, Sandhu, Girardi, & Khan, 2002) It is equally important to define the success from the patient's perspective as the patient perception of improvement and his/her goal achievement is the purpose of every health care plan.(Deyo et al., 1998; Mannion, Junge, et al., 2009) The patient is likely to experience successful surgical outcomes when their expectations about surgery are fulfilled.(Mannion, Junge, et al., 2009) Therefore, many self-reported questionnaires have been developed to assess patient perception of the surgery outcomes to assess the success of spinal surgeries.(LaCaille, DeBerard, Masters, Colledge, & Bacon, 2005; Mannion, Porchet, et al., 2009a, 2009b; Trief, et al., 2006)

Many studies have investigated possible pre- and post-surgical factors predicting short- and long-term outcomes. A systematic review of outcomes of spine fusion showed 64% of patients had "good-to-excellent" prognosis.(Turner, Ersek, Herron, & Deyo, 1992) Patients rated LSS success with a more variable range between 25-63%.(Brox, 2003; Fritzell, 2001) Therefore, various studies concluded that some patients continue to complain of pain and disability after successful fusion surgery; (Penta, 1997; Turner et al., 1992) in addition the failure rate of LSS is estimated to be 2-8% of the cases. (McAfee, 1999; Onesti, 1998; Turner, Ersek, Herron, Haselkorn, et al., 1992) Hereafter, investigating pre- and post- surgical factors is warranted to optimize surgery outcomes.

Given the multidimensional improvement following LSS, we studied the predictors of pain, function, general health, somatic perception, and patients' perception. Since some of these outcomes are not routinely assessed and documented in medical records, we had to study the predictors of these outcomes prospectively (chapter 4).

1.2.4 Intraoperative factors determining lumbar spine surgery outcomes

Surgery outcomes have been associated with variable intraoperative factors.(Nahtomi-Shick et al., 2001; Sharma et al., 2012; Zheng, et al., 2002) Nahtomi-Shick et al., (Nahtomi-Shick, et al., 2001) reported that total intraoperative crystalloid (solutions of mineral salts) administration, American Society of Anesthesia score (ASA) physical status, surgical procedure (decompression with or without fusion, anterior or posterior approach, or complex surgeries), and total intraoperative platelet administration are significant predictors for length of stay in the intensive care unit following LSS. (Nahtomi-Shick, et al., 2001) Zheng and colleagues (Zheng, et al., 2002) reported number of spine levels operated, postoperative hemoglobin and hematocrit values, total volume of blood transfused, and operative time as predictors of LSS outcomes.

Types of surgery and number of spinal levels operated are well documented to be a source of variation in surgical outcomes. Deyo and colleagues, (Deyo, Cherkin, Loeser, Bigos, & Ciol, 1992) retrospectively determined that patients who had fusion surgery had more complications during hospitalization, more days at hospital, and more hospital charges compared to laminectomy and discectomy. Also, the number of pathological spine levels that needed operation had an association with the surgery outcomes. (Sharma, et al., 2012; Turner, Ersek, Herron, & Deyo, 1992) From the abovementioned studies, the intraoperative factors are important factors that determine the surgery outcomes. Understanding its correlations with surgical outcomes will make it possible to have realistic expectations about patient's status after surgery. These variables are examined to determine DP and LOS following LSS.

1.2.5 Physical therapy intervention following LSS

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Typically, physical therapy (PT) assessment is conducted on the same day or next day of surgery. The assessment includes:

- Mental and cognitive status

- Pain: intensity, location, frequency, quality and other pain descriptors

- Social history: family support, type of house, and home accessibility

- Range of motion and muscle strength.

- Neurological assessment/ sensory assessment

- Bed mobility and transfer: including type of assistant needed, any assistive device needed, and balance and coordination

- Gait: including walking distance, any assistance needed, and any assistive devices used

- Stairs at home and the ability to go up and down stairs at hospital

Based on the initial PT assessment, some patients may require continued PT services while hospitalized. PT intervention is usually individualized. Physical therapists, after completing assessment, might include one or more of the following interventions:

- Education on bed mobility, sitting, standing, walking, stair climbing, use of assistive devices and how to manage activities of daily livings

- Exercise to improve mobility, strength and endurance

- Balance training

- Functional training

- Gait and stair training and other ambulatory training

There is lack of evidence supporting the effectiveness of inpatient physical therapy.(Christensen, 2004) Nielsen and colleagues (Nielsen, Jorgensen, Dahl, Pedersen, & Tonnesen, 2010) compared two rehabilitation protocols in patients who underwent spinal

surgeries. A combined treatment of pre- and immediately post-surgery has been shown to be more effective in reducing LOS and increasing patient's satisfaction in comparison to PT services post-surgery alone. However, the combined intervention was not superior to standard post-surgery PT intervention (control group) in pain and function outcome measures. (Nielsen, et al., 2010) The study did not show strong evidence for the benefits of inpatient physical therapy, possibly due to the lack of a control group. The weak evidence to support inpatient PT may explain why PT management is routinely prescribed by some surgeons, and not by others: Surgeons' recommendations and practice patterns after LSS are highly variable;(Cenic & Kachur, 2009; McGregor, 2010; McGregor, Dicken, & Jamrozik, 2006; Williamson, White, & Rushton, 2007) some surgeons consider nursing care rather than PT for immediate rehabilitation, or find it enough to give patients written instructions on PT-related post-operative management. Others recognize the need for both physical therapists and nursing care. The decision for PT consultation and PT treatment may depend on the individual patient case, as there are no screening processes to determine who needs PT services and who does not. <u>This is the long-term goal of our study as identifying various predictors of postsurgical outcomes aimed to identify patients who may benefit from PT services.</u>

Early physical therapy assessment as predictors of surgical outcomes

Inpatient PT assessment and re-assessment is a part of the clinical decision-making process.(DeJong et al., 2011) However, PT assessment is rarely studied as a possible predictor for short- or long-term outcomes after LSSs. Sharma and colleagues (Sharma, et al., 2012) conducted a retrospective review of 100 medical records for patients with spinal fusion or discectomy. LOS was significantly correlated with number of inpatient PT encounters and the

functional dependence score comprised of pre- and post-surgical patient functions assessed by a physical therapist. When functional dependency score and number of inpatient physical therapy encounters were entered in a regression model, together they explained 66% of the variation in the LOS. This study illustrates the importance of inpatient PT assessment and how earlier functional assessment could be used to predict surgical outcomes. Although these variables seem to be potential predictors, they are rarely studied as predictors of surgery outcomes. Therefore, we are planning to use multiple early postoperative PT assessment to predict short term (2 weeks after discharge) pain and functional outcomes after surgery.

1.3 Length of hospital stays following lumbar spine surgery

Length of hospital stay (LOS) is defined as the number of nights patients spent in hospital from the day of admission to the day of discharge. A patient admitted and discharged on the same day has a length of stay equal to 0.(Wier, et al., 2009)

Surgery-related LOS's vary with the type and severity of surgical procedure. Variability in LOS for the same surgery type also exists, with differences in LOS found among national regions and countries and even among different surgeons of the same health care center.(Clarke, 1996) For instance, spinal fusion is usually accompanied with a higher LOS in comparison to laminectomy and discectomy.(Deyo et al., 2010) The average LOS for cervical and lumbar spine discectomy and laminectomy surgeries is 2 days. (Beth Israel Deaconess Medical Center, 2012) Average LOS of a heterogeneous sample of discectomy, laminectomy, and fusion is 3.3(Deyo, et al., 2010) to 5.7 days.(Andreshak, An, Hall, & Stein, 1997) The LOS for patients who had laminectomy or fusion ranged between 1.3 to 4.1 days. Less invasive surgical procedures, such as microrndoscopic decompression, result in a significantly lower LOS compared to the more

invasive open decompression (42 and 94 hours of LOS respectively).(Khoo & Fessler,

2002) Similarly, LOS following less invasive lumbar microdiscectomy was significantly less

than more invasive microdiscectomy.(German, Adamo, Hoppenot, Blossom, & Nagle, 2008)

In the current health care system, there is an increasing demand to shorten the LOS, while

providing safe discharge and appropriate discharge destination with continuous community care

(Shepperd, S., 2004; Shepperd, Sasha, 2009; Shepperd, S. et al., 2010). The aims of reducing

LOS are to: 1) individualize treatment according to the availability of the community care, 2)

free hospital resources, 3) reduce the overall spending and the resources needed to take care of

patients.(Clarke & Rosen, 2001) Consequently, healthcare providers may be expected to be more

efficient in providing hospital care and in initiating hospital discharge. The financial pressure

from the payers, such as government or private insurance companies, may compromise optimum

and adequate care and speed the transition from hospital to community care. In fact, self-payer

patients typically stay longer after spine surgeries than patients covered by government or private

insurance.(Walid, Zaytseva, Barth, & Robinson Jr, 2012)

In general, a short inpatient LOS, when hospital stay may still be needed, may negatively

impact prognosis, and subjects may require more postoperative care upon discharge and may rely

more on family care. (Mauerhan, 2003) Prior to discharge, patients receive their medication

plans and education about resuming daily activities such as driving, lifting, sexual activities,

returning to work or school, and resuming strenuous activities. Yet, after discharge, patients are

not directly or medically supervised, which may lead to poor prognosis in patients with shorter

LOS. After early discharge, patients will be more reliant on social support, such as family

members, which requires extensive family education and necessitates more time and labor from

the involved health care members. As a result, some patients receive referral for outpatient

rehabilitation. Short LOS may also be accompanied with anxiety. (Clarke & Rosen, 2001) On the other hand, longer LOS is associated with adverse effects such as nosocomial infections, muscle weakness, and deep vein thrombosis. It is not clear whether the longer LOS is associated with complications or results from it. (Clarke & Rosen, 2001)

1.3.1 Length of stay and quality of health care

Hospital cost accounts for the largest component of health care expenditure, which is estimated to be around 31% of total health costs in the United States.(Cowan, Catlin, Smith, & Sensenig, 2004) Therefore, there is a demand on the health care providers to provide efficient care to reduce LOS and identify factors related to LOS. Data shows a trend of decline in LOS over time in many regions of the world.(Clarke & Rosen, 2001) As an example a recent study showed that in 14 veterans affairs hospitals in the US, LOS decreased approximately 27% between 1997 to 2010, meanwhile the re-admission decreased with mortality rates significantly decreased.(Kaboli, 2012)

LOS is an important indicator of efficient inpatient care and an important measure of performance.(Clarke, 1996; Clarke & Rosen, 2001; Ricci, et al., 2006) The inpatient stay requires expenses of supplies, nursing care, medications, physical therapy (PT) and occupational therapy (OT) services, and follow up visits by physicians. (Zheng, et al., 2002) The more time the patient spends in the hospital, the more costly the health care will be.

Therefore, it will be important to identify factors that predict LOS to establish care delivery models for those patients based on measurable factors and associated with standard care of delivery (Chapter 1). Establishing such models will facilitate efficiency in health care delivery and increase satisfaction of patients and healthcare providers.(Cowan, et al., 2004) Also, study

factors that affect the LOS will allow health caregivers to understand modifiable factors that they can treat to improve surgery outcomes. Determining these factors will guide pre-operative evaluation to identify people who are at higher risk of lengthier LOS, needs assistance and rehabilitation facility, and poorer outcomes after surgery.

1.3.2 Predictors of length of stay

There are multiple and diverse factors associated with LOS. Clarke in a relatively old literature review(Clarke, 1996) suggested that these factors could be classified into supply and demand factors:

Supply factors include practice style whether it varies in the heath care centers across regions, among centers in the same region, or among surgeons within the same center. One large multicenter study reported a significant difference in practice style between 13 spine clinics in 11 states.(Desai et al., 2012) This variation could result in variation in LOS and outcome measures. For instance, the differences in the hospital discharge policy including the level of illness for which hospital care is considered desirable have implications in varying the LOS across hospitals. LOS depends on the availability of bed supply, hospital competition, and the quality and availability of primary, community, or convalescent care. Another supply factor is the payment method. In accordance with what has been previously mentioned, patients treated under health maintenance organizations have significantly shorter times in the hospital than those treated under fee for service plans. (Bradbury, Golec, & Stearns, 1991; Clarke, 1996) In our study, supply-related factors are not as important as demand factors as the data were taken from the same hospital serving patients living in the surrounding community, although their payer sources may vary.

The underlined demand factors associated with LOS are the speed of patient's recovery and the quality of health care provided. For example, complications during or after surgery, the presence of comorbidities and increased disease severity may require an increase in LOS in relevance to speed of patient's recovery.

Another way of classifying factors affecting LOS could be grouping the factors into three categories: patient factors, clinical factors, and treatment factors.(Epps, 2004)

1-Patient factors: age, sex, race, and living situation

2-Clinical factors: comorbidities and pre-operative physical status indicator (total lymphocyte count and hematocrit), and body mass index (BMI) as indicator of body fat

3-Treatment factors including surgical factors: operation time, type of anesthesia, post-operative analgesia and complications

Predictors of LOS in spine surgery

Predicting LOS following lumbar spine surgery using multiple predictors was the aim of few retrospective studies. Regression models were formulated using several variables to explore predictors of LOS. Sharma and colleagues (Sharma, et al., 2012) in a sample of mixed type of lumbar spine surgeries found that age, number of surgical levels, number of physical therapy visits, functional dependency score (combined score of prior level of function and functional dependency during inpatient stay), sex, discharge destination, and type of surgery were significantly associated with LOS. However, only functional dependency and the number of inpatient PT encounters were significant predictors that predicted 66% of the variation in LOS.

Zheng and colleagues (Zheng, et al., 2002) retrospectively reviewed 112 medical records for patients who underwent posterior lumbar spine decompression and fusion. They explored

possible intraoperative and postoperative factors that could predict LOS. Age, number of spine levels fused, postoperative hemoglobin and hematocrit levels, and total volume of blood transfusion were significantly correlated with LOS. However, regression model revealed that only age was significant predictor that predicted 21% of the variation in LOS. Nahtomi-shick et al., (Nahtomi-Shick, et al., 2001) reviewed 103 medical records for patients with mixed type of spine surgeries (decompression with or without fusion) in different areas of the spine (cervical, thoracic, or lumbar). The authors concluded that American Society of Anesthesiologists (ASA), physical status, type of surgical procedure, volume of fluid transfused, and age were significant predictors for intensive care unit LOS.

These previous retrospective studies had limited sample size and considered limited possible predictors in their regression models. Factors that were correlated but not significant could be classified as preoperative (age, sex, ASA score, and prior level of function), operative (type of surgery, number of levels operated, and volume of fluid or blood transfused), or postoperative (postoperative hemoglobin and hematocrit levels, postoperative dependency score, number of PT encounters during inpatient stay, and discharge destination). Among these factors, only age, ASA score, type of surgery, volume of fluid transfused, dependency score (pre- and postoperative), and number of PT encounters were significant predictors. These studies show inconsistent results, explain a small percentage of variation for LOS, and do not include many variables as potential predictors of LOS. Considering a larger sample size and including more variables as possible predictors in a model are needed to explain a higher variation in LOS.

Other studies confirmed some of the aforementioned results. In addition, these studies revealed additional factors that could be used as possible predictors and may affect LOS following spine surgery.

Increasing age has been found to be a significant predictor of LOS, and the LOS is significantly different between different age groups. One study reported a significant difference in LOS between patients older than 65 years in comparison to younger patients who underwent lumbar fusion.(Jo, Jun, Kim, & Kim, 2010) Increasing age is always linked with longer period of LOS because of increased number of comorbidities and increased rate of postoperative complications. Kilinçer and colleagues(Kilincer, Steinmetz, Sohn, Benzel, & Bingaman, 2005) studied the effect of age on the outcomes of posterior lumbar fusion surgery. A significant difference in LOS was found between older age group (>65) in comparison with the younger age group (<65), but no difference was found in number of complications, estimated blood loss, and operative time, which suggest other physiologic factors may mediate the difference in LOS with age in this group. Walid et al., (Walid, et al., 2012) in a mixed sample size of cervical and lumbar spine surgeries reported Charlson comorbidity index to be a significant predictor of LOS and total hospital costs. In a group of patients between 66 to 80 years of age who had various types of spine surgeries, there was a modest but statistically significant effect of age, race, and sex on LOS. (Deyo, et al., 2010)Meanwhile LOS increased with increasing comorbidities and previous spine surgery.

In an old retrospective study of 30 medical charts of subjects who had lumbar laminectomy, researchers classified LOS to be short (6 days or less), moderate (7-8 days), and long (9 days or more). (Neatherlin, Brillhart, & Henry, 1988) Number of analgesic taken by patients, and presence of postoperative muscle spasm were significantly different between the 3 groups for LOS. Sex, postoperative administration of steroids, presence of complications, age, and operation time were not statistically different.

These studies revealed that comorbidities, postoperative complications and postoperative pain would be possible variables to study the predictability of the LOS. Increasing sample size and entering more factors in prediction models would increase the prediction accuracy, explain variability associated with various factors and provide a greater understanding of the factors contributing to the LOS. It would be important to understand why some factors are significant predictors and some are not. Structural equation model (SEM) could be used to study multiple factors and improve our understanding of how these factors influence each other.

Predictors in orthopedic surgeries

Since there is shortage of studies related to LOS in lumbar spine surgery, it could be feasible to have insight from parameters influencing LOS following similar studies in orthopedic surgeries like cervical spine surgery, head and neck surgery, total hip arthroplasty (THA), and total knee arthroplasty (TKA) to study LOS following LSS with SEM.

A retrospective study for 103 medical records of patients who underwent anterior cervical spine surgery, explored multifactor for predicting increased LOS.(Arnold et al., 2011) Among many pre- and postoperative factors, only age, sex, and the presence of postoperative cardiac, urinary, and pulmonary complications were significant predictors. In a similar study with head and neck surgery, sixty-eight variables (preoperative, intraoperative, and postoperative variables) were tested as predictors of prolonged LOS.(BuSaba & Schaumberg, 2007) Older age, poor functional status, consumption of more than two drinks of alcohol per day, history of chronic obstructive pulmonary disease, and diabetes mellitus patients stayed longer in hospital. Operative time and transfusion of erythrocytes were the only significant intraoperative predictors

of LOS, while occurrence of more than two complications was the only significant postoperative predictor.

In a study of 712 THA and TKA surgery patients , Husted and colleagues(Husted, Holm, & Jacobsen, 2008) found that age, sex, marital status, co morbidity, preoperative use of walking aids, pre- and post-operative hemoglobin levels, the need for blood transfusion, American Society Anesthesiology (ASA) score, and time between surgery and physical mobility were correlated with LOS. Schneider and colleagues (Schneider et al., 2009) found similar results showing age, pre- and post-surgery mobility, home situation, and ASA score influencing the LOS following TKA and THA. In addition, they reported clinical diagnosis and the use of pre-operative medications were also important factors. In the Epps study, (Epps, 2004) only postoperative complications were the predictors and explained 22.3% of the variation in LOS in subjects with TKA and THA.

A study in Denmark with 712 patients admitted for TKA and THA surgery at specialized fast-track unit.(Husted, et al., 2008) Several pre- and postoperative factors were correlated with LOS including: age, sex, marital status, co-morbidity, preoperative use of walking aids, pre-and postoperative hemoglobin levels, the need for blood transfusion, ASA score, and time between surgery and mobilization. A study in Finland with large sample size (n=15,461) of patients undergoing TKA and THA reported that postoperative complications, age, and sex influenced the LOS.(Rissanen, Aro, & Paavolainen, 1996) A large sample size study in Scotland with unilateral THA patients used a multivariate regression model to explore factors associated with reduced length of stay. Younger age, male sex, high hip function and activity score, high 36-item quality of life questionnaire, use of non-steroidal anti-inflammatory drugs were significant predictors.

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The review of these studies allowed identification of additional factors as predictors of LOS in various orthopedic surgeries and could potentially be considered to examine LOS following LSSs. Several pre-operative factors were either correlated or predictors of LOS such as age, sex, marital status, home situation, alcohol consumption, use of non-steroidal anti-inflammatory drugs, use of walking aids, mobility level, functional status, high function and activity score, high 36-item quality of life questionnaire, comorbidities, ASA score, hemoglobin levels, and clinical diagnosis. Intraoperative factor were operative time, blood transfusion, time between surgery and physical mobility. The postoperative factors included complications (cardiac, urinary, and pulmonary complications, and diabetes mellitus), hemoglobin levels, and post-surgery mobility.

Considering the contribution of these factors from other orthopedic surgeries, these factors could also be considered as predictors for LOS in lumbar spine surgery and should be investigated. The factors are marital status, home situation, alcohol consumption, use of non-steroidal anti-inflammatory drugs, use of walking aids, post-surgery physical mobility. Other potential factors for LOS in lumbar spine surgeries that were not reported in other orthopedic surgeries are postoperative hematocrit levels, postoperative dependency score, and number of PT encounters during inpatient stay, and discharge destination. A model combining all factors may provide a greater understanding of predictors of LOS following lumbar spine surgeries and the variability explained by these factors.

We framed a structural equation model with 3 latent variables and one manifest variable and studied their contribution to the variation in LOS. The 3 latent variables are presurgical, surgical, and postsurgical factors. In this study we used a structural equation model (SEM) of analysis that allowed testing of complex interrelationships between multiple variables and how

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each of these variables affected the endogenous or the dependent variable LOS. Also, in this model we can arrange different factors in separate groups and study their effect as latent variable.(MacCallum & Austin, 2000) (Chapter 1)

1.4 Discharge placement

Reduction of the health-related cost is becoming a major interest in health care system.(Shepperd, S. et al., 2013) There is current trend in health system to decrease LOS and duration of inpatient care, and increase discharge to rehabilitation unit such as skilled nursing facility (SNF) and inpatient rehabilitation (IR), or to community based.(Clarke & Rosen, 2001) LOS following total joint arthroplasty decreased from 6.4 days in 1995 to 5.1 in 1997, while during the same period, discharge to rehabilitation units increased from 13% to 33% of the patients. (Forrest, G. P., Roque, & Dawodu, 1999) Jerman and colleagues (Jarman, Aylin, & Bottle, 2004) reported similar trend when they compared LOS and discharge placement (DP) in the USA and England: the LOS is 6.7 days in Medicare hospitals compared to 26.9 days in the National Health Service hospitals in England for people aged 65 and over. This huge variation could be explained by the obvious trend in the US for early discharge and discharge to intermediate care: 39% of the patients in the US were discharged to intermediate care, compared with 10% in England. With the recent trend to decrease LOS of inpatient care and the movement towards more community-based care, policy of discharge planning is becoming widely adopted.(Shepperd, S., et al., 2013)

1.4.1 Discharge planning

Discharge planning starts soon after surgery, and an interdisciplinary team is involved in the process. The aim of the discharge planning is to bridge the gap between hospital care and community care after discharge. (Shepperd, S., 2004; Shepperd, Sasha, 2009; Shepperd, S., et al., 2010) Discharge planning involves developing an individual patient plan, preparing the patient to leave the hospital and safely transition into community care.(Shepperd, S., et al., 2013) Individualized discharge plan can reduce hospital readmission and consequently readmission costs.(Shepperd, S., et al., 2013) Also, early discharge planning allows early communication between hospital and community service providers, which can prevent delay in discharge for non-medical reasons.(Shepperd, S., et al., 2013)

The patient is a key factor in the discharge planning process. Family is also an important part of patient care when patients are discharged to home. (Morrow-Howell & Proctor, 1994; Popejoy, 2011) The options of discharged placement are discussed with the patient and his/her family when available. Family support provides continuous community care for patients who are not back yet to their presurgical functional level. The level of family involvement in discharge planning depends on the relationship between family members, the level that family involvement, the amount of support required, and the directions of health care team.(Popejoy, 2011)

Effective discharge planning involves early prediction of the patient's physical function upon discharge.(Sivertson, Öberg, & Sernert, 2010) Early PT assessment of functional level includes assessment of bed mobility, transfer, sitting and standing balance, and gait distance and assistance. These factors could be used to assess current functional level and to predict the functional level upon discharge and level of assistance the patient needs following discharge.

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However, these factors have been rarely used to predict surgery outcome including prediction of LOS, DP, and functional status following discharge. In addition to medical stability and physical function, the availability of healthcare resources is a major factor in determining the DP,(Sivertson, et al., 2010) as well as social support.(Jackson, Whisner, & Wang, 2013)

1.4.2 Discharge placement

There are many options for discharge depending on patients' need. Patients can be discharged to their home where patients in need will continue to receive assistance either from their family or a skilled care assistance, or discharged to intermediate care like SNF and IR to continue treatment before going to home.

Discharge to home

Some patients could be discharged to home with being either totally independent, need family assistance, or need skilled care assistance at home. At home, patients may need assistance with activities of daily living (ADL), such as feedings, bathing, dressing, toileting, and getting in or out of bed. Patients may also need help in instrumental ADLs such as housekeeping, shopping, transportation, administering medication, or handling finances. (Li, Morrow-Howell, & Proctor, 2004) The level of support needed upon hospital discharge is determined by the health care providers' judgment of the patient's medical status and functional ability and willingness of the patient and family to be involved.

If family assistance is not available or the patient needs skilled assistance beyond family's assistance/ability, the patient may be discharged to home with skilled assistance, home health services or outpatient PT. Home health services is part of the continuous care following

discharge, where patients medical and functional recovery, and rehabilitation could be continued at their residential place which is more cost effective in comparison to the SNFs.(Helbing, Sangl, & Silverman, 1992) To be eligible to receive home health services under Medicare policy, the patient should be confined to home and cannot leave home without assistance due to restriction caused by illness or injury. (Lawonn, 2012) These patients are likely to need intermittent skilled health services such as nursing along or nursing care along with at least one of the following therapeutics services: PT, speech therapy, occupational therapy, home health aide services, and medical social services. These services are provided at place of residence.(Department of health and human services: centers for Medicare & Medicaid services, 2012)

Another discharge option is home with outpatient PT or rehabilitation services. Patients are referred to this service when they are medically stable and not confined to home, but need rehabilitation skilled services to facilitate their return to the previous level of function and to maximize independency. In this category, the patient does not need continuous care, rather needs outpatient services that are designed to upgrade the physical function of handicapped and disabled individuals.

Discharge to intermediate care

When the patient lacks progress or needs further rehabilitation to reach his/her optimal functional level, the multidisciplinary team members may suggest patient's discharge to an intermediate care. (de Pablo et al., 2004) Moreover, this decision could also be taken in circumstances where social support or family assistance is not available. This kind of decision is usually taken with consideration of the individuality of the case, and when there is absence of factors that could determine discharge place to home or to IR/SNF.(de Pablo, et al., 2004)

IR is a specialized rehabilitation unit of acute care hospital or specialized inpatient rehabilitation hospital.(Department of health and human services: centers for Medicare & Medicaid services, 2012) This unit provides intensive rehabilitation services to patients who are expected to benefit from staying at the hospital due to their medical management needs and from an intensive interdisciplinary rehabilitation approach (typically 3 hours, 5 days a week). The hallmarks of IR are the interdisciplinary approach, intensity of the rehabilitation therapy services, and physician supervision.(Department of health and human services: centers for Medicare & Medicaid services, 2012) Patients are required to have physician approval, no more surgeries, needing at least two skilled therapy services, and have the physical and cognitive capacities to benefit from the rehabilitation.(Lawonn, 2012)

SNF is a specialized facility where residents receive primarily skilled nursing care. Residents also receive related health care services such as rehabilitation services.(Department of health and human services: centers for Medicare & Medicaid services, 2012) The patients who are discharged to this facility must require skilled nursing care or skilled rehabilitation service or both. (Lawonn, 2012)

In this project we will study factors that predict discharge to home with or without skilled assistance, or will be discharged to intermediate care whether it was IR or SNF (Chapter 3).

1.4.3 Discharge placement following lumbar spine surgery

In a prospective study, surgery outcomes of more than 5000 consecutive spine surgery cases operated by 19 physicians were reported. The surgical procedure was either elective or emergency-based for numerous causes. In this study, 86.2% of patients were discharged to home,

8.9% to rehabilitation center, and 2.5% to SNF.(Theodosopoulos et al., 2012) Sharma and colleagues reported that following LSS of discectomy and fusion, 78% of the patients were discharged home and 22%were discharged to subacute sitting (IR/SNF).(de Pablo, et al., 2004; DeJong, et al., 2011; Mallinson, 2011; Sharma, et al., 2012) A quite similar percentage (77%) of patients were discharged home after having kyphoplasty between 1993 and2004 and the remaining were discharged to either SNF or IR.

There is lack of studies regarding DP following LSS. Deyo et al.,(Deyo, et al., 1992) explored registry database to study predictors of discharge to SNF versus home following lumbar spine surgery. Age, sex, primary diagnosis, and surgery type were studied as predictors. Only age and sex were significant predictors in logistic regression analysis. The risk of being discharged to SNF increased 4.2 times for every 10 years increment in age, while being female increased the risk of being discharged to SNF by 3.4 times. In another study, 90 patients had vertebroplasty surgery, (Harvey & Kallmes, 2011) and pain intensity at rest and at activity was measured before and after the surgery. The 4 pain intensity measurements were not significantly correlated with DP.

In a more recent study, Deyo and colleagues (Deyo, et al., 2010) explored the surgical outcomes of the 32,152 cases of Medicare claims for older patients who underwent mixed types of spine surgery for stenosis between 2002 and 2007. The percentage of patients discharged to SNF was significantly higher in older age groups (66-70, 71-74, 75-79, <80 years), in females, in white race, with increasing number of comorbidities (0, 1, 2, 3 or more), with increasing past LOS after being admitted for non-spine problem (e.g. cardiac arrhythmia), type of surgical procedure (decompression alone, simple fusion, or complex fusion), and number of levels operated (1-2, 3 or more). Using a multivariable logistic regression method with adjustment for

demographics and clinical variables, the type of surgery was a significant predictor. The surgery type was significant in Deyo et al.,(Deyo, et al., 1992) earlier study, but was not significant in Deyo et al.,(Deyo, et al., 2010) more recent study (2010). The difference may be explained by how they were entered in the model or may be due to the difference in surgery types in the two studies.

Following LSS, it seems that a considerable percentage of patients are not discharged to home and need further health care assistance. Age and sex, and type of surgery, but not pre and post operation pain or primary diagnosis, could be significant predictors. Other possible predictors need to be investigated in regression models as predictors and include: race, number of comorbidities, previous hospital admission or previous spine surgery, and number of levels operated. These results need to be confirmed and several other factors should be investigated to determine which factors can predict DP. We will also review similar orthopedic surgeries to know which factors could be studied as predictors for DP in LSS in addition to the aforementioned variables, as studies determining DP following LSS are limited.

1.4.4 Predictors of discharge placement following fracture

Sivertson and colleagues(Sivertson, et al., 2010) built a prediction model using inpatient PT assessment factors only to predict DP following neck of femur fracture in elderly population (range 66-95). They reported that postoperative elderly mobility scale (Swedish version), age, living status, and PT recommendation (PT evaluation) for DP are correlated with DP. Timed-up-and-go test and pre-fracture mobility did not correlate with DP. Early mobility, age, living situation, were the only significant predictor of DP.(Sivertson, et al., 2010) These results highlight the importance of PT assessment factors as predictors of DP and possibly similar

predictability in LSS. In a similar population, Kimmel et al., (Kimmel et al., 2012)   found that

age, presurgery work status, site of the fracture within the limb, compensation for their

admission, healthcare payment, living region (metropolitan or rural), and self-reported disability

prior to injury were significant predictors of discharge to inpatient rehabilitation.

A large database for older adults, who experienced trauma in various parts of their body

from falls, was retrospectively explored for factors predicting discharge to home, SNF, or

IR.(Lim, Hoffmann, & Brasel, 2007) Multivariate analysis showed that female and white patients

were more likely to be discharged to SNF. Patients who had Medicare insurance were more

likely to be discharged to SNF or IR rather than to home. Patients who had more severe injury,

had high trauma score, or needed intensive care unit were less likely to be discharged home.

Patients who suffered spine injury were more likely to be discharged to IR more than patients

with injury to other body parts. In another large (n=495) nationally representative sample of

patients with hip fracture, researchers used multinomial regression to study predictors of

discharge placement: (home, IR, or SNF). Patients with falls or dementia were more likely to be

discharged to IR more SNF. Patients who had insurance other than Medicare were most likely to

be discharged to IR or SNF rather than home. The following factors were not significant: LOS,

age, sex, race/ethnicity, living situation, education, number of comorbidities, self-reported health

status, ADL activity index, and cognitive status interview score.

A study included approximately 90 thousand medical records of patients aged at least 65,

who were admitted with hip fracture in New York state hospitals between 1986 and

1996.(Aharonoff, Barsky, Hiebert, Zuckerman, & Koval, 2004) Age, sex, race, surgical

technique, comorbidities, LOS, and year of admission were examined as possible predictors of

discharged to SNF. Multiple logistic regression analysis showed that significant predictors to

SNF were 85 years and older age, female sex, white race, having more than 3 comorbidities, and history of dementia.

In another study, data were collected from 197 facilities across the US with a total sample size of 176, 419 patients who received IR with different diagnosis.(Jackson, et al., 2013) Outcome measured used as predictors of discharge to IR were 18-item functional independence score (FIM), age and diagnosis (stroke, joint replacement, lower extremity fracture, and other diagnoses). They used exploratory factor analysis method to reduce the number of items to be included in a structural equation model (manifest variables) to a smaller set of variables. Following exploratory factor analysis, 5 items of Functional Independence Measures were indicators of cognitive FIM latent variable, 10 items were indicators of physical performance FIM latent variable, age, and diagnosis were tested using structural equation modeling method. Final model results showed that only 4 items were indicator for cognitive FIM, and 3 items were indicator of physical performance FIM. The rest of the variables were removed from the model. The study concluded that cognitive and physical FIM had strong predictive power of IR (odds ratios: -0.255, and -0.827 respectively).

In a similar study included Medicare patients with stroke, congestive heart failure, and hip fracture. The researchers investigated the factors predicted DP (home vs. SNF and home vs. IR) who received discharge planning.(Morrow-Howell & Proctor, 1994) Factors predicting discharge to SNF more likely than to home were higher levels of functional dependency upon discharge, increased cognitive impairment having either Medicaid or private pay resources, being single, and being Caucasian. Meanwhile, having hip fracture or stroke, more dependent upon discharge, having private pay sources, and living alone were more likely to be discharged

to IR rather than home. These two studies highlighted the importance of level of function and level of cognition as predictors for DP.

In summary, these previous studies show that several factors could be predictors of being discharged to either IR or SNF including: older age, sex (female), race (white), living situation (alone), payment source (Medicare), presurgery work status (unemployed), living region (rural), prior level of function, comorbidities, declined cognitive function (dementia), severity and location of injury, and postoperative mobility. However, there was inconsistency between the studies because not all of these factors were significant in all studies. Age as a patient factor influencing discharge disposition is not conclusive. Most of the studies found patients who were discharged to IR/SNF had higher number of comorbidities. This inconsistency might be explained by different sample size, heterogeneity of the sample, number of variables tested in the models, and the correlation between variables tested as predictors.

1.4.5 Discharge placements following joint replacement surgery

Clinical, demographic, and clinical data of 7,818 medical records for patients underwent unilateral TKA and THA were retrospectively reviewed.(Bozic, Wagie, Naessens, Berry, & Rubash, 2006) Results concluded that age, sex, ASA, type of insurance, and primary versus revision surgery significantly predicted DP. Epps (2004) found that age, sex, living situation, comorbidities, and postoperative complications were significant predictors of DP following TKA and THA.(Epps, 2004) Race, postoperative total lymphocyte count and hematocrit, BMI, type of anesthesia, operation time, and type of postoperative analgesia were not significant.

A relatively old retrospective study with low sample size (n=125), Forrest and colleagues (1998) studies variables correlated with DP following THA and TKA.(Forrest, G., Fuchs,

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Gutierrez, & Girardy, 1998) Age and having diabetes showed a significant correlation with DP but were not significant predictors of DP. Forrest et al., (Forrest, G. P., et al., 1999) studied predictors of DP in 129 patients with total joint arthroplasty. They concluded that age, sex, ASA score, surgeons, and living situation are associated with DP (discharge home or rehabilitation unit). Using logistic regression, age, ASA score, living situation were the only significant predictors.

A longitudinal prospective study concluded that older patients, females, living alone, having 4 comorbidities or more, and walking shorter distance are more likely to be discharged to IR following THA. (Félix & Fritzsche, 2004) Munin et al., (Munin, Kwoh, Glynn, Crossett, & Rubash, 1995) compared the difference between patients discharged to IR and patients discharged home following TKA and THA. Patients discharged to IR were more likely to be older, living alone, had higher number of comorbidities, higher pain intensity, and lower functional measures.

In another large sample size study, cohorts of patients were recruited from multiple centers to study predictors of discharge to IR or home following THA. (de Pablo, et al., 2004) In primary and revision THA age, sex, living situation, education level, income, obesity, inability to walk before discharge were significantly correlated with DP. Female sex, older age, living alone, low income, obesity, and inability to walk independently before discharges were significant predictors of being discharged to IR.

Age, sex, ASA score, income, type of insurance, living situation, and comorbidities (especially diabetes) were relatively common between all the studies. Functional factors were common also such as preoperative level of function, postoperative walking distance, and inability to walk before discharge. Some factors were not common such as primary or revision

surgery, complications, postoperative pain intensity, education level, and obesity. Factors that did not show even correlation were mostly surgical factors including: postoperative total lymphocyte count and hematocrit, type of anesthesia, operation time, and type of postoperative analgesia.

Studies that explored predictors of DP in LSS were very limited. Studies in LSS and comparable orthopedic surgeries showed that multiple preoperative factors, pre and postoperative functional factors, and to limited extent surgical factors could be studied as predictors of DP following LSS.

1.4.6 Discharge placements and follow up

When outpatient services are prescribed, studies have shown positive benefits in optimizing the outcomes of spinal surgeries. (Cenic & Kachur, 2009; Williamson, et al., 2007) A systematic review by Ostelo and colleagues(Ostelo, et al., 2003) evaluated the effectiveness of active rehabilitation after first time lumbar disc surgery. The review indicated that studies that had protocols of immediate treatment after surgery were of poor quality and lack strong evidence. For the rehabilitation programs starting 4-6 weeks after surgery, there is strong evidence of effectiveness of intensive exercise program on functional outcomes and return to work in the short- and long-term follow up (12 months); however, intensive exercise was more effective than mild exercise program in the short-term only. (Ostelo, et al., 2003) Supervised exercise and home exercise were equally effective in low quality randomized controlled trials. Similarly, there was weak evidence that multidisciplinary care was not more effective than the usual daily care on global perceived effects, sick leave, or operation rates. Finally, in this review the aerobic exercises showed no significant addition to post-surgical rehabilitation. Recently, the

effectiveness of rehabilitation programs including exercise was studied, and biopsychosocial rehabilitation was effective in improving the outcomes after laminectomy and fusion surgeries. (Mannion, Denzler, Dvorak, Muntener, & Grob, 2007; Soegaard, 2006) Outpatient PT services were shown to have positive benefits on optimizing the outcomes of spinal surgeries. (Cenic & Kachur, 2009; Williamson, et al., 2007) Also, there is a lack of studies related to factors describing the need for health care services (e.g. PT). (Cenic & Kachur, 2009; Williamson, et al., 2007) <u>Therefore in our study, we will investigate factors that predict pain, functional status, and quality of life after 2 weeks of discharge, so we can have early expectation and better guidelines of which patient is likely to benefit from future outpatient PT.</u>

1.5 Predictors of short and long term lumbar spine surgery outcomes

The main purpose of LSS is to reduce pain and improve function; however, this purpose is not always achieved. A systematic review of outcomes of spine fusion showed 64% of patients had "good-to-excellent" outcomes and the success range reported in the literature was highly variable: between 16% to 96%. (Turner, Ersek, Herron, & Deyo, 1992) Although discectomy has a comparatively high success rate, it is still 75% to 80%.(Atlas, Keller, Chang, Deyo, & Singer, 2001; Atlas, Keller, Wu, Deyo, & Singer, 2005) Only 70% of patients who had surgical management for disc herniation reported improvement in their predominant complain after 5 and 10 years of surgery.(Atlas, et al., 2001; Atlas, et al., 2005) Patients with laminectomy reported improvement in pain and function between 52 to 90%. (Bouras et al., 2010; Javid & Hadar, 1998) Therefore, it may be concluded that some patients continue to experience pain and disability after LSS. (Penta, 1997; Turner, Ersek, Herron, Haselkorn, et al., 1992) In addition, the

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failure rate of LSSs is estimated at 2 to 8% of the cases. (McAfee, 1999; Onesti, 1998; Turner, Ersek, Herron, Haselkorn, et al., 1992)

Predictors of LSSs have been extensively examined. Many studies have used multiple outcome measures/predictors such as pain and function. The variables used as predictors include, but not limited to: sociodemographic and work related, clinical, psychological and emotional variables. Retrospective studies were more common than prospective because the large sample size required for constructing regression models is more conveniently collected in retrospect. Short- and long-term surgery outcomes have been investigations using numerous predictors including presurgical, surgical and postsurgical variables, although studies are primarily limited to the analysis of presurgical. The most common surgery outcomes used were pain, function, general health, resuming normal activity, returning back to work, multidimensional improvement, and patient's perception of improvement. (Carragee, Han, Suen, & Kim, 2003; DeBerard, LaCaille, Spielmans, Colledge, & Parlin, 2009; den Boer, Oostendorp, Beems, Munneke, & Evers, 2006a; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Gaetani et al., 2004; LaCaille, et al., 2005; Mannion, Elfering, et al., 2007; Nygaard, Kloster, & Solberg, 2000; Trief, et al., 2006) The follow up period ranged from 6 weeks to 10 years.

A systematic review of prospective studies investigating predictors of lumbar disc surgery is available.(den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006) The included articles were those published between 1980 and 2003, with a sample size of at least 30 participants at baseline, and whose primary purpose was to study predictors of the LSS outcomes. Only 11 studies matched the inclusion criteria. The main outcome measures (dependent variables) were pain, disability, and work capacity. The authors concluded that several sociodemographic, clinical, and work-related factors can be significant predictors of the

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outcome measures. The most consistent potential predictors in these studies were: education level, preoperative pain, presurgery work satisfaction, longer duration of sick leave, anxiety, somatic perception, pain coping strategies, and depression. Another systematic review included only prospective studies of preoperative variables predicting surgical outcomes of lumbar stenosis surgery that were published before April 2005. (Aalto et al., 2006). Only 21 studies met these criteria. Patients' satisfaction, pain intensity, walking capacity, and function were significant predictors. Age, sex, education, clinical examination, marital status, and obesity were not significant predictors in most of the studies. Preoperative good health status and functional ability predicted better outcomes after surgery. Patients who had low depression level and ambitious expectations had better outcomes after surgery whereas patients with longer duration of symptoms and pain predominantly in the low back area predicted worse outcomes.

A more recent systematic review included 21 studies, of both prospective and retrospective designs, published between 1966 and 2008. (Celestin, Edwards, & Jamison, 2009) The original search was restricted to studies investigating psychosocial variables as predictors, and LSS outcomes were assessed after at least 6 months of surgery. The majority of studies found that pain intensity and multiple pain locations predicted poor surgery outcomes. Higher level of depression, and anxiety were predictors of negative outcomes. Similarly, somatization and hypochondriasis predicted poorer outcomes. In approximately half of the studies, functional variables were used as predictors. A higher presurgical disability level and a lower level of self-reported activity were significant predictors of poor outcomes. Older age and female sex were associated with poor outcomes in approximately half of the studies, when demographic variables were available. Finally, when including the duration of the symptoms as a predictor, a consistent association with poor outcomes was found.

1.5.1Predictors of long term surgery outcomes

In a retrospective study of subjects receiving worker's compensation following a lumbar discectomy between 1994 and 1999, age, litigation, and time delay between injury and surgery were significant predictors of disability and return to work, while time delay was a predictor of analgesic use.(DeBerard, et al., 2009) Having previous surgery in addition to age and litigation were significant predictors of patient's self-reported surgery outcomes as measured by the Stauffer-Coventry Index, specifically the physical restriction subscale. Finally, age, depression, litigation, assignment of case manager, and time delay were significant predictors of quality of life (QOL) measured using the SF-36 survey. A similar earlier retrospective study of subjects receiving worker's compensation between 1990 and 1995 (DeBerard, Masters, Colledge, Schleusener, & Schlegel, 2001) investigated presurgical sociodemographic factors to predict long term lumbar fusion surgery outcomes (an average of 4.6 years). Age, income at time of surgery, litigation, depression and number of prior low back operation were significant predictors of permanent disability, Stauffer-Coventry Index, pain, and physical functioning and social functioning subscales of the SF-36 survey. These two studies included medical records for patients who received spinal surgery approximately 15 years ago. As such, the outcomes following current surgical procedures would be different. Moreover, the two studies included a specific population, which limits the generalizability of the findings. However, both studies display the importance of predicting function and ability to return to work as important dimensions of improvement. These studies also demonstrate the importance of considering work related and socioeconomic factors as possible predictors of other outcomes of surgery such as general health and type of analgesic used.

A retrospective review with prospective follow up was conducted to predict lumbar fusion surgery outcomes. (LaCaille, et al., 2005) The average follow up period by phone calls was 2.6 years after surgery. The LSS success as measured by the subsequent fusion rate was high (in 84% of the sample); conversely the outcomes reported by patients were much lower. 50% subjects indicated pain was worse than expected; 63% believed that surgery outcomes were poor; and 38% of the subjects were considered disabled, with lower general health scores compared to their same-age peers. The severity of the disease score from the presurgical spine imaging was a significant predictor of disability status with litigation. Litigation with smoking and depression were significant predictors of the physical component score (PCS) of the SF-36 survey and the functional score measured by the Ronald Morris Questionnaire (RMQ). The technical success of the surgery is not an ideal representation of the patient's perceived success of the surgery. Therefore, we can conclude that the success of surgery should be considered as a multidimensional success of numerous health related outcome measures. Interestingly, preoperative work status, independent of the presence of workers' compensation, predicted work status after more than one year (average 2.5 years) of anterior lumbar fusion.(Anderson, Schwaegler, Cizek, & Leverson, 2006) In addition to preoperative work status, smoking history, sex, workers' compensation, age, preoperative pain intensity, preoperative RMQ score, number of spine level fused, and the type of cage used in the fusion were studied as predictors of postoperative work status, and of the change in VAS and RMQ from presurgery to postsurgery. Only preoperative work status predicted postoperative work status. In the meantime, only presurgical VAS predicted changes in VAS, and none of the variables predicted RMQ score.

Predictors of treatment outcomes were retrospectively studied in subjects receiving workers' compensation and two groups were compared: a group who had lumbar fusion and a

group who had nonsurgical management.(Nguyen, 2011) The study aimed at identifying the predictors of returning to work after 2 years of surgery, and compared the predictors to the nonsurgical group. In stepwise logistic regression analysis, age, sex, body mass index, diagnosis, smoking history, weekly wages, legal representation, marital status, education, total days off, time between injury and surgery, presence of complications, radiological findings, number of rehabilitation sessions received, opioid dose, fusion approaches, and discogram performance were the independent variables predicting the dichotomous dependent variable (returning to work, not returning to work). In the surgical group, weekly wages, presence of complications, time between injury and surgery, legal representation, morphine dose, and reoperation were significant predictors of work status. The number of days off from work and weekly wages were significant predictors in the nonsurgical group. Although both groups were assessed at baseline, the surgical management group showed distinctive predictors of long term outcomes.

A Swedish study randomized patients with chronic LBP into surgical (fusion) and nonsurgical management (Hagg, Fritzell, Ekselius, & Nordwall, 2003) and studied the predictors of improvement in both groups. Potential predictors studied were age, sex, occupation, work status, marital status, comorbidity, workers' compensation , LBP duration, duration of sick leave, having previous surgeries, and smoking, Karolinska Scale of personality, pain assessment, disability status (ODI), clinical finding (e.g. back range of motion, motor system assessment, and sensory motor assessment), and radiological findings. Dependent variables were assessed at 2 years follow up including patient's perception of improvement in back pain, disability, and work status. Neurotic personality, a disc height loss more than 50% in surgical group, and depressive symptoms for the non-surgical group were the only significant predictors for patient perception of improvement. Only neuroticism was the predictor of disability in the surgical group, and none

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were found to be significant predictor in the other group. Finally, short sick leave was a significant predictor of working status in both groups, but age was significant in the surgical group only. In this study, the presurgical psychological factors outweighed the sociodemographic and other factors predicting patients' perception of improvement after surgery, highlighting the importance of assessing these factors for clinical and research purposes.

A study reported smoking more than 10 cigarettes before the surgery was a predictor of nonunion after 2 years of surgery, and cessation of smoking after surgery reduced the risk of nonunion.(Andersen et al., 2001) In the same study, being older than 60, being unemployed, and having more than one level fused were also predictors of nonunion. Similarly, smokers who continued to smoke after surgery had a nonunion rate of 25.6%, while those who quit smoking had a significantly lower rate at 14.2%.(Glassman et al., 2000) Patients are usually asked to quit smoking before the LSS, because nicotine is reported to delay early vascularization and may consequently delay healing from surgery and bone graft union.(Andersen, et al., 2001) Smoking status would be an important predictor to consider while examining surgery outcomes.

Whether the emotional health before lumbar spine fusion surgery will predict pain and function after 12 and 24 months of surgery was studied prospectively. (Trief, et al., 2006) The Mental Component Score of the SF-36 (MCS) was collected at baseline and used as an independent variable to predict the following outcome measures: pain intensity, PCS, and disability level measured by ODI. These outcome measures were likewise assessed preoperatively and also used as predictors. Independent variables also used in the prediction models were age, sex, height, weight, worker's compensation, current smoking, revision of surgery needed, leg pain, and back pain, all of which were collected at baseline. The presurgical MCS was a significant predictor of pain, PCS, and ODI in the two follow-up periods. Significant

predictors of postoperative PCS or ODI were worker's compensation, smoking, second surgery needed, preoperative PCS, MCS, and preoperative ODI. Predictors of ODI were worker's compensation, smoking, second surgery needed, MCS, and ODI were significant predictors of back and leg pain the two follow up periods. The regression models explained between 25%-35% of the variation in the response variable, a relatively good score in clinical research. Although many factors were controlled for in the model at baseline, authors did not control for the predicted outcome at baseline. However, this study presented the importance of preoperative emotional status as predictors for postsurgical outcomes. The importance of including several outcome measures as various predictors (e.g. emotion, pain, function, general health, and work status) is also emphasized. Although many predictors were included in the study, a high percent of the variation in the outcome measures still needs to be explained.

A recent study examined cognitive behavioral variables as predictors of 12 months outcomes following lumbar disc surgery. (Johansson, Linton, Rosenblad, Bergkvist, & Nilsson, 2010) Leg pain, back pain, function measured by ODI, quality of life measured by the European Quality of life questionnaire (EuroQol-5D-5L), and being on sick leave were assessed preoperatively as potential predictors and postoperatively as outcome measures. Patients' belief of return to work, fear avoidance and coping strategies were only assessed preoperatively. Patients' belief for a chance to return to work predicted all the outcome measures. Low fear avoidance and female sex significantly predicted low QOL. No additional predictors showed to be significant.

Kleinstück et al. (Kleinstück, 2009), in a study including 221 patients who underwent decompression surgery, assessed back pain intensity(LBP), leg pain intensity (LP), and the difference between LP and LBP (LP-LBP). The Core Outcome Measures Index (COMI) was

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assessed at baseline and at follow up. COMI is a multidimensional index that includes a

validated questionnaire addressing several dimensions of improvement (e.g. pain, function,

QOL). After adjusting for age, sex, comorbidities, and COMI, several regression models were

used to study the best predictors of the COMI and global outcome measures of patients

perception (surgery did help, or surgery did not help) after 12 months of surgery. LBP were

significant predictors of COMI, and LP-LBP was the only significant predictor for global

outcome measures. The higher the preoperatively intensity of LBP, the worst the COMI was, and

a higher difference between LP and LBP was associated with better outcomes after 12 months.

LBP explained around 19% of the COMI after 12 months. Adjusting for other variables like

psychological outcome measures at baseline might suggest different results although presurgery

pain factor would be an important factor to consider in any prediction model. This study

uniquely assessed the difference between leg pain and back pain as predictors, because previous

studies had showed leg pain greater than back pain to be associated with better outcomes.(Atlas,

et al., 2005)

Trief and colleagues (Trief, 2000) studied prospectively the predictors of lumbar

fusion/decompression after one year of surgery. The potential predictors were: socioeconomic,

work status, level of anxiety (assessed using Beck's Anxiety Inventory (BAI)), level of

depression (assessed using Beck's Depression Inventory (BDI)), somatic perception (assessed by

Modified Somatic Perception Scale(MSPQ)) and hostility, while the outcome measures were

return to work, and change in back and leg pain. Presurgical employment, receiving disability

funds, somatic perception and depression were significant predictors of postsurgical work status.

Somatic perception and depression were significant predictors of patient's perception of change

in back and leg pain. In addition to the preoperative psychological status also found as an

important predictor of postsurgical outcomes and ability to return to work, preoperative level of depression was a predictor of disability and pain intensity after two years of surgery.(Sinikallio et al., 2011)

Comorbidities could determine surgery outcomes. A recent Japanese study showed that patients with diabetes at the time of surgery consistently report higher back pain, leg pain, and leg numbness after one year of surgery compared to non-diabetics. (Takahashi et al., 2013) Nonunion fusion is significantly different between diabetic and non-diabetic patients.

To summarize, the above studies predicted LSS long-term outcomes, after one year up to approximately seven years of surgery. The outcome measures used in these studies varied and included: leg pain, back pain, leg numbness, type of analgesic used, disability and functions measured by ODI or RMQ, quality of life measured by SF-36 or EuroQol-5D, being on sick leave, return to work, disability status with litigation. Also, the studies used multidimensional outcome measures as COMI, global outcome measures that includes patients' perception of improvement in back pain, disability, and return to work. The potential predictors assessed could be classified into these categories:

- Demographic: age, sex, height, weight, body mass index, occupation, marital status, and education.
- Clinical variables: pain intensity (leg pain, back pain, and leg-back pain), clinical findings (e.g. back range of motion, motor system assessment, sensory motor assessment, and Lasegue's sign).
- Functional level (ODI and RMQ), and quality of life (EuroQol-5D-5L, SF-36)

- Cognitive and psychosocial variables: fear avoidance scale, pain coping strategies, anxiety, depression, somatic perception, hostility, type of personality (e.g. Neurotic personality), and depression.

- Medical variables: comorbidities, smoking , LBP duration or time between injury and surgery, radiological findings (e.g. disc height loss and severity or disease), diagnosis, presence of complications, number of rehabilitation sessions received, opioid dose, and use of medication.

- Surgical variables: revision of surgery needed, having previous surgery, fusion approaches, assignment of case manager, and having more than one level fused.

- work related factors: being on sick leave, duration of sick leave, patients' believe of chances to return back to work, worker's compensation, work status, weekly wages, legal representation, total days off from work, litigation, income at time of surgery, and being unemployed

- Global assessment including patients' perception of improvement and COMI

1.5.2 Predictors of short term surgery outcomes

Mannion and colleagues (Mannion, Junge, et al., 2009) assessed patients' expectation for improvement in leg pain, back pain, walking capacity, independence in everyday activities, general physical capacity, ability to sport, social wellbeing, and mental wellbeing. For each of the 7 items, patient rated their expectation as "much better", "better", "somewhat better", "unchanged", and "worse". Subjects were also asked to rate their back pain, leg pain, and functional status using RMQ. At 2 months and 12 months follow-ups, patient's perception of improvement in the previous 7 items, a global effectiveness of surgery, back pain, leg pain, and

functional status (RMQ) were assessed. With multiple linear regression models predicting leg pain, back pain, and disability at 2 and12 months, patient's expectation was not a significant predictor for any of the dependent variables. In a hierarchical multiple regression analysis predicting global effectiveness of surgery while controlling for sociodemographic and preoperative clinical factors (months in treatment for the back problem, number of other joint problems, general health, and baseline pain intensity), patients' expectation was not significant when added to the model. However, the change in pain intensity (leg or pain) was significant when added to the model. Similarly, the difference between patients' expectations before the surgery and actual patients' perception of improvement were significant predictors. 2 months hierarchical multiple regression analysis showed similar results at 12 months. In addition, "having other joint problems" was a significant predictor. From this study, the predictors of short term follow up could be similar to the predictors of the long term follow up. However, short term follow up was found to be more correlated with preoperative factors in comparison to long term follow up.

Block et al.,(Block, Ohnmeiss, Guyer, Rashbaum, & Hochschuler, 2001) conducted a study to highlight the importance of presurgical psychological data on postoperative pain, function and medication use after approximately 9 months of LSS. At one month before surgery, semi-structured interviews and psychological questionnaires were completed including the Minnesota Multiphasic Personality Inventory-2 and Coping Strategies Questionnaires. Using hierarchical logistic regression, all elements of the psychological questionnaires were significant predictors of patient's perception of surgical outcomes. Worker's compensation, work load, family reinforcement and obesity were also significant predictors. den Boer and colleagues (den Boer, Oostendorp, Beems, Munneke, & Evers, 2006b) explored the role of cognitive-behavioral

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and work related factors as risk factors for not returning to work after 6 months of lumbar disc surgery. A controlled logistic regression was used to control for demographic (age, sex, and education) and clinical (preoperative disability, preoperative pain, symptoms duration, and type of analgesic intake) variables. Cognitive behavioral variables were assessed preoperatively, including negative outcome expectations, fear of movement, passive pain coping, and medications intake. Work related factors were work physical load score, job satisfaction, and duration of sick leave. Multivariate logistic regression results showed that fear of movement, passive coping strategy, and physical work load predicted ability to return back to work. Preoperative multiple cognitive and psychological variables were significant predictors for the short term outcomes.

Another study recruited subjects who had discectomy and investigated multivariable as presurgical predictors. (Kohlboeck, 2004) Among these factors, presurgical clinical assessment of straight leg raise, pain duration, and radiculopathy at baseline were included to predict pain intensity and location, functional capacity, return to work and general health after six months of surgery. Using a hierarchical cluster analysis, the outcome measures were classified into 3 groups: "success group", "socially unintegrated group", and "poor outcome group". Straight leg raise range of motion, depression, and sensory description of pain were the only significant predictors.

The predictors of multidimensional outcomes after 6 months of decompression/fusion surgery were determined by combined pain, function, symptom-specific well-being, quality of life, and work outcome measures in an index score (core outcome measures index (CORE). (Mannion, Elfering, et al., 2007) 34% of the variation in the CORE index was explained by baseline CORE, medical variables (pain duration, previous spine operations, number of levels

treated, and operative procedure), and psychosocial factors (fear avoidance scale, and depression scale). medical variables were better in predicting pain and symptom-specific wellbeing , while the psychological predictors were better in predicting back function, general well-being, and disability using hierarchical multiple regression.

Patients in Ireland were assessed before undergoing lumbar discectomy surgery and 3 months after surgery to identify preoperative risk factors for persistent postsurgical pain.(Hegarty & Shorten, 2012) Possible presurgery predictors were age, sex, pain duration, anesthesia duration, operation time, dermatomes affected, positive straight leg raise, presence of nerve compression, pain intensity (present pain intensity, visual analogue scale, and the McGill pain questionnaire), RMQ score, pain coping scale, hospital anxiety and depression scale, and PCS and MCS of SF-36. The only significant predictors were age, present pain intensity, and RMQ score. Although the study used many predictors, a few were found as significant. This study is unique in using data from surgery to predict postsurgical outcomes, in contrast to most studies that predicted outcomes based on preoperative outcomes. In our study, we will exploit the immediate postsurgical data (e.g. operation time, estimated blood loss) and inpatient PT assessment to predict short-term outcomes (2-weeks following hospital discharge).

Den Boer et al., (den Boer, Oostendorp, et al., 2006a) studied the predictability of presurgical cognitive-behavioral factors on disability and pain after 6 weeks and 6 months of LSS. The cognitive-behavioral outcomes were pain-related fear of movement (adjusted Tampa Scale of Kinesiophobia), passive pain coping (Pain-Coping inventory), and negative outcome expectancies. The baseline measures that showed correlation with disability and pain after surgery were pain and disability level before the surgery, age, sex, education level, and neurological deficits after surgery. These variables were controlled for in the prediction model.

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Pain level after 3 days of surgery was also correlated and entered in the model after controlled variables. Cognitive-behavioral variables were added last into the model. Cognitive-behavioral factors showed a significant correlation with pain and disability. Immediate postoperative pain explained 13% and 7% of the variation of disability in 6 weeks and 6 months respectively, while Cognitive-behavioral factors explained 4% and 7% of the variation. Immediate postoperative pain explained 23% and 12% of the variation of pain intensity in 6 weeks and 6 months consecutively, while the cognitive behavioral factors explained 4 and 5% of the variation. This study highlighted the importance of cognitive behavioral factors and pain intensity immediately after surgery to predict short and long term pain and disability. Postoperative pain could explain higher percentage of variation in the short term more than long term. <u>In our study, we will use preoperative pain and other immediate postsurgical outcomes to predict outcome measures in as early as 2 weeks following discharge from hospital (chapter 4 and 5).</u>

To summarize, the literature in this section explored predictors of surgical outcomes assessed from 6 weeks up to 12 months. The main outcome measures used were: pain intensity, pain location, disability/function, symptom-specific well-being, quality of life, and CORE outcome measures, medication used, patient's perception of improvement in back pain, leg pain, and functional status, a self-reported global effectiveness of surgery, and return to work. Predictors used in the prediction models were:

- Demographic: age, sex, and education.
- Clinical: Preoperative pain intensity and pain location, pain intensity 3 days after surgery, and straight leg raise range of motion.
- Disability /Function: activities of daily living, general physical capacity, ability to sport, social wellbeing, and mental wellbeing, RMQ.

- Cognitive and psychosocial: pain-related fear of movement, passive pain coping, negative outcome expectancies, depression and anxiety levels, expectation of improvement in leg pain, back pain, and walking capacity, and type of personality.

- Medical and surgical variables: pain and symptoms duration, previous spine operations, number of levels treated, type of surgery, type of analgesic intake

- work related factors: work load, work status, job satisfaction, and duration of sick leave

- Global assessment including patients' perception of improvement, COMI, and CORE

The predictors which were significant were fear of movement, passive coping strategy, physical work load, straight leg raise range of motion, depression, and sensory description of pain, The change in pain intensity (leg or pain), patients' perception of improvement, and elements of the psychological questionnaires were significant predictors of good and bad outcome.

There is inconsistency in research regarding the most important predictors of LSS outcomes and their predictive power. (Mannion, Elfering, et al., 2007) The inconsistencies in the findings could be due to study design (retrospective versus prospective), variability and number of predictors, types of surgery, and presurgical diagnosis. (Mannion, Elfering, et al., 2007) There is also variation in the studies regarding the type of outcome measures assessed, and the way the predictors and outcome measures were assessed. In our study we will study the outcome of the surgery using a more comprehensive outcome measures in two relatively short term periods to reduce the confounding factors which might occur in long term follow up (chapter 4 and 5).

At present, the literature examined the predictors of LSS examined the outcome measures mostly in long term follow up and the earliest follow up was 6 weeks following surgery. In our study, we aim to predict surgical outcomes as early as 2 weeks after hospital discharge (chapter 4

and 5). Only few immediate postsurgical outcomes including surgical PT assessment outcomes were included in a very limited number of studies predicting short term outcomes like LOS and DP. (Nahtomi-Shick, et al., 2001; Sharma, et al., 2012; Zheng, et al., 2002) Therefore, in our study we will independently assess immediate postsurgical variables as predictors of postsurgical outcomes (chapter 5).

1.6 Significance of research

LBP is becoming more epidemic in our modern society, with a major impact on individuals, the health care system, and the economy. LSS is a common treatment for LBP when conservative management fails to treat pain and improve function. Nonetheless, surgery results are not always positive, and patients' complaints may be unchanged or sometimes worsen. It has been noted that there are determinants for surgery success and mainly include preoperative variables predicting pain, function, general health status, patient's perception of improvement, return to work and other measures of improvement. In our study, we will expand on the study of determinants and include possible predictors of surgical and postsurgical outcomes using surgical variables and inpatient PT assessment. In our study, we propose to extend this knowledge by investigating determinant of LOS, DP, and early post discharge surgical outcomes.

We propose to study risk factors and determinants of LSS "success" to highlight the importance of collecting these factors upon entry, after surgery, and after discharge. Consequently, this project aims at optimizing health care planning and clinical decision making in discharge planning and identifying the need for follow up of other therapies. Results of this

study will assist in enhancing patient selection for surgery via prediction of patient outcome after the surgery.

This research is expected to benefit patients and their families, health care providers, and healthcare service managers. Predicting LOS and DP, and early postoperative outcomes will allow patients and their families to prepare for possible early discharge. Also, it will allow them to prepare for the need of health care following discharge and early weeks of discharge. Identifying predictors of surgery outcomes will permit safe transition from hospital to community care.

LOS is an important indicator of efficient inpatient care and performance. Surprisingly, there is limited research investigated predictor of LOS following LSS, despite extensive investigation of LOS following other orthopedic surgeries. LOS studies following LSS are characterized by small sample size, limited number of factors used as predictors of LOS, and lack of multidimensional outcomes to explain the variation in the LOS. In our study, we propose to include a large sample size from medical charts, using factors from pre-surgery, surgery, and from inpatient PT records. We propose to use structural equation model analysis that could explain the variation in the LOS and also can explain the collinearity between factors contributing to LOS. Such analysis will provide a more comprehensive understanding of the multidimensional determinants of LOS and illustrate the importance of each variable, or group of variables, so we can identify the factors that define LOS more precisely.

Although studies of predictors of DP in other orthopedic surgeries (hip and knee replacement) and in many neurological conditions (stroke and brain injury) are plenty, to our knowledge, no study has investigated the predictors of DP following LSS. We retrospectively investigated predictors of DP in order to understand factors that could determine to where

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patients are more likely to be discharged: home or intermediate care (IR/SNF). Potential predictors were preoperative factors and surgical factors, and the role of PT assessment was incorporated in the prediction model, a novel approach not considered before. Also, we used predictors to identify which patients will likely need skilled assistance or will be able to manage activities of daily living without skilled assistance (e.g. assistant from family) upon discharge. Understanding these factors will help clinicians in making decisions about the level of care needed following hospital discharge and will facilitate setting more realistic post-surgery expectations by patients, family members and caregivers.

The literature reporting presurgical factors as predictors for short term and long term surgical outcome measures (6 weeks to10 years) is abundant. However, no study has investigated the postsurgical outcomes as early as 2 weeks following hospital discharge. We have chosen a short term period for assessment to reduce the confounding factors which might occur in long term follow up. At 2 weeks of discharge, patients usually have an outpatient visit to the clinic for reassessment and seek additional health care services if necessary. Identifying outcomes during this period may allow patients to better understand their condition and prepare for their medical/rehabilitation needs after 2 weeks, while recovering from surgery. Within the same scope, this will also aid in estimating the level of assistance needed at discharge and identifying patients who may need closer follow up after surgery. Finally, identifying early surgery outcomes will help in providing patients with more individualized instructions and restrictions upon discharge. Finally, an estimation of when the patient can resume normal life including return to work may be made.

We are proposing a prospective study because many important outcome measures (e.g. fear avoidance) are not routinely assessed before surgery. We also collected intraoperative data

from medical charts and assessed patients' functional outcomes during inpatient hospital stay, as predictors of pain and functional status after 2 weeks of discharge, as using immediate post-surgical variables in prediction models could improve our predictions of the outcomes.

1.7 Specific aims and statement of hypothesis

Our <u>long term goal</u> is to predict patients' LOS and DP, and identify patients who are likely to benefit from health care services after hospital discharge, based on preoperative, intraoperative and early post-surgery inpatient PT assessment variables. The <u>objectives</u> of the present proposal are to 1) retrospectively establish structural equation models for LOS after LSSs using various outcome measures taken from a large sample database (n=1000), 2) retrospectively determine the predictors that determine discharge status to home or intermediate care, and need for skilled assistance (e.g. PT) once patients are discharged to home, and 3) prospectively study the correlation and predictability of short- and long-term health status after LSS using preoperative measures.

Specific Aim 1: Retrospectively formulate a structural equation model using multiple variables to explain variation in length of hospital stay after lumbar spine surgeries of laminotomy, laminectomy or fusion (chapter 2). The purpose of this study is to develop a SEM to explore presurgical, surgical, and postsurgical variables that predicts LOS following LSS, and examine the relationship between these variables. Several potential predictors were used as indicators (manifest variables) to construct three factors (latent variables), presurgical, surgical, and post-surgical factors, to predict LOS. *We expect this SEM will significantly fit the*

data (hypothesis 1a). Also, *we hypothesize that the latent variables will have significant direct*

effect on LOS (hypothesis 1b).

Aim 2: Retrospectively determine predictors of discharge placement after LSS and level of assistance needed after patients being discharged to home. Prediction of DP following

hospital stay has been determined in several orthopedics surgeries such as vertebroplasty

(Harvey & Kallmes, 2011) and total hip or knee replacement (de Pablo, et al., 2004; DeJong, et

al., 2011; Mallinson, 2011). Using prediction models in these surgeries, age, obesity, ability to

walk, (de Pablo, et al., 2004) pre-admission living status,(de Pablo, et al., 2004; Harvey &

Kallmes, 2011), and functional status upon discharge (DeJong, et al., 2011) were significant

predictors of DP. However, predictors of DP following LSSs have not been investigated. We

expect many presurgical, surgical and postsurgical variables will be correlated with discharge

placement following LSS. *We expect the significantly correlated variables will be significant*

predictors of being discharge to home or to inpatient rehabilitation/skilled nursing facility

(hypothesis 2a). For patients who will be discharged home, we expect the significantly

correlated variables will be significant predictors of who will need skilled assistant or who will

not need skilled assistant (hypothesis 2).

Specific Aim 3: Prospectively, to determine preoperative variables that can predict short term multidimensional surgical outcomes following lumbar spine surgeries of discectomy, laminectomy, or fusion. Studies have shown that multivariable could predict short and long

term multidimensional health outcomes.(Carragee, et al., 2003; DeBerard, et al., 2009; den Boer,

Oostendorp, et al., 2006b; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006;

Gaetani, et al., 2004; LaCaille, et al., 2005; Mannion, Denzler, et al., 2007; Nygaard, et al., 2000; Trief, et al., 2006) However, to our knowledge no studies have investigated short term outcomes as early as 2 weeks following discharge from hospital. Therefore, w*e hypothesize that multiple sociodemographic variables, psychological variables, and clinical variables will be significant predictors of multidimensional outcomes including: back pain, leg pain, function, quality of life, and patients' perception of improvement (hypothesis 3).*

Chapter 2

Structural Equation Model Analysis of the Length of Hospital Stay Following Lumbar Spine Surgery

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2.1 Abstract

Background context: Length of hospital stay (LOS) after lumbar spine surgery (LSS) can be affected by many surgical and non-surgical factors. However, little is known about what factors affect LOS.

Purpose: To build a structural equation model to identify variables that significantly predict LOS following LSS.

Study Design/Setting: A retrospective review of medical records from October, 2008 to April, 2012 from the University of Kansas hospital.

Patient Sample: 593 medical records of patients who had LSSs of laminotomy, laminectomy or fusion.

Outcome Measures: Patients' demographics, LOS, intensive care unit length of stay, body mass index, hemoglobin and hematocrit levels, volume of fluid resuscitation, use of assistive device, surgery type, previous surgeries, diagnosis, pain intensity and location, home situation, home type, prior level of function, dependency score, balance, gait distance, gait assistance, severity of illness, complications number, admission day of the week, and number of comorbidities.

Methods: A structural equation model was built following identification of significant variables that constructed three latent factors: presurgical, surgical, and postsurgical. These factors were then studied to predict LOS following LSSs.

Results: The average LOS was 4.01±2.73 days. The following variables were significant indicators of the 3 latent factors: presurgery: age (61.97±14.49 years) , prior level of function (60.5% were totally independent), hemoglobin level before surgery (13.70±1.36 mg/dl), use of assistive devices (60%); surgery: severity of illness (50.2% had minor disease severity), having complications (1.9%), need to stay intensive care (4.0%); and post-surgery: walking distance

(166.43±175.75 feet), level of assistance during gait training (5.18±0.81 out of 7 points), sitting and standing balance combined score (6.18 ±1.82 out of 10 points), and bed mobility and transfer dependency score (9.81± 1.99 out of 14 points). Postsurgical factors independently explained 19% of the total 47% variation in LOS explained by the model.

Conclusion: Age, prior level of function, use of assistive device, and presurgical hemoglobin level are important presurgical indicators. Severity of illness, postoperative complications, and intensive care unit stay are key surgical variables to predict LOS. Following the surgery, physical therapy functional assessment predicts the highest variation in LOS in comparison to presurgical and surgical factors. Thus functional assessment should be weighted more in consideration for discharge planning.

Key words: Lumbar laminectomy, lumbar fusion, back pain, length of stay, surgery outcomes, functional assessment, structural equation model, physical therapy

2.2 Introduction

Lumbar spine surgery (LSS) is a common procedure for treatment of lumbar spine stenosis, sponylolysis, spondylolisthesis, disc herniation, and other causes of low back pain. Discectomy is increasingly becoming ambulatory surgery, while laminectomy and fusion normally require hospitalization (Gray, et al., 2006). LSS rate in the United States is the highest in the world, with high surgery costs and related postsurgical care (Schiller, et al., 2012; Weinstein, J. N., Lurie, Olson, Bronner, & Fisher, 2006). Hospital costs account for the largest portion in health care expenditure, which is estimated to be around 31% of total health costs in the United States (Cowan, et al., 2004). Hospital inpatient stay requires expenses related to supplies, nursing care, medications, physical therapy (PT), occupational therapy, physicians follow-up visits, and other ancillary services(Zheng, et al., 2002). Thus, reducing length of hospital stay (LOS) would be cost effective.

LOS is an important indicator of efficient inpatient care and performance (Clarke, 1996; Ricci, et al., 2006). Evidence suggests trend of declining LOS over time in many regions of the world (Clarke & Rosen, 2001). The aim for reducing LOS is to free up hospital resources for management of other critical cases and reduce the cost of surgery and related health care (Clarke & Rosen, 2001). Nevertheless, the short inpatient stay may have a negative consequence on prognosis (Mauerhan, 2003). Early discharge requires extensive family education as patient may rely on family care and require more follow up care after discharge. Conversely, longer LOS is associated with adverse effects such as nosocomial infections, muscle weakness, and deep vein thrombosis.

It is important to study factors that predict LOS to establish care delivery models, which facilitates efficiency of health care delivery and satisfaction of patient, family, and healthcare

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provider (Cowan, et al., 2004). Furthermore this would permit early goal-setting and early discussion of intervention and discharge destination plans with patients, their families, healthcare providers, and healthcare payers. Identifying LOS predictors may allow healthcare providers to identify modifiable factors that can be addressed to improve surgical outcomes. Finally, determining LOS predictors could allow early identification of potential limitations in patient case and establish plan of care accordingly, and facilitate communication of current treatment plans with other healthcare facilities (e.g. skilled nursing facility).

Few retrospective studies have examined LOS following LSS (Deyo, et al., 2010; Nahtomi-Shick, et al., 2001; Sharma, et al., 2012; Walid, 2011; Zheng, et al., 2002) and identified many variables that correlated with LOS. These variables can be classified as presurgical (age, sex, American Society of Anesthesiologists (ASA) score, comorbidities, and prior level of function), surgical (type of surgery, number of levels operated, and volume of fluid or blood infused), or postsurgical (postoperative hemoglobin and hematocrit levels, postoperative dependency score, number of PT encounters during inpatient stay, postoperative complications and discharge destination). Among these factors, age, ASA score, type of surgery, volume of fluid transfused, dependency score, number of PT encounters, and postoperative complications were significant predictors (Deyo, et al., 2010; Nahtomi-Shick, et al., 2001; Sharma, et al., 2012; Walid, 2011; Zheng, et al., 2002). Variables such as marital status, home situation, preoperative use of walking aids, clinical diagnosis, and postsurgery physical mobility have been investigated to predict LOS following other orthopedic surgeries (Arnold, et al., 2011; BuSaba & Schaumberg, 2007; Epps, 2004; Husted, et al., 2008; Schneider, et al., 2009), but have not been studied as possible predictors of LOS following LSS.

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Increasing sample size and inclusion of more variables may increase the prediction accuracy and explain higher percentage of variability in LOS. One of the major challenges to study LOS is that many variables are multidimensional and correlated with each other, resulting in inconsistencies in the results and inability to select the best variable in the model. Structural equation model (SEM) allows for testing of relationships among many variables, construction of latent variables that cannot be measured directly and estimating the values of parameters. Thus, SEM would be a useful method of analysis to illustrate the factors that predict LOS while showing correlations between these factors (MacCallum & Austin, 2000).

The purpose of this study was to develop a SEM to explore presurgical, surgical, and postsurgical factors that could predict LOS following LSS, and examine the relationship between these factors. Several potential predictors were used as indicators (manifest variables) to construct three factors (latent variables), presurgical, surgical, and post-surgical factors, to predict LOS. We expected that these latent variables will have significant direct effect on LOS.

2.3 Methods

Data source

We extracted de-identified data from the University of Kansas hospital (KU hospital) and clinics electronic medical records (Epic Corporation) and other administrative, research, and public sources such as the clinics' billing system (GE IDX), the University Healthsystem Consortium (UHC, https://www.uhc.edu), tumor registries, and the social security administration death index. Our study protocol did not require Institutional Review Board approval because of de-identified data extraction, but received approval from the HERON (Healthcare Enterprise Repository for Ontological Narration) oversight committee.

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Cohort of the Study

We reviewed patient records of those who underwent LSS at the KU hospital between October, 2008 and April, 2012. We identified our cohort of interest on HERON system using the i2b2 query and analysis tool (Murphy et al., 2010) using CPT codes to identify subjects who had posterior LSS: laminotomy, laminectomy, and fusion (arthrodesis). We used i2b2 query and analysis tool to identify our inclusion and exclusion criteria. Medical records for patients 18 years or older who had at least one PT encounter (PT visit) during inpatient stay were included. Medical records were excluded for patients with history of neoplasm, intraspinal abscess, spinal deformity (i.e. scoliosis, kyphoscoliosis), spine fractures, vertebroplasty, osteomyelitis, and cauda equina syndrome. Based on these criteria, 614 records were identified. We also excluded medical records that did not have formal LOS data from billing records.

Selection of covariates

In i2b2 query and analysis tool, covariates of interest were selected based on relative research (Carragee, et al., 2003; de Pablo, et al., 2004; DeBerard, et al., 2009; DeJong, et al., 2011; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Gaetani, et al., 2004; Harvey & Kallmes, 2011; LaCaille, et al., 2005; Mallinson, 2011; Mannion, Elfering, et al., 2007; Nygaard, et al., 2000; Sharma, et al., 2012; Trief, 2000; Trief, et al., 2006; Zheng, et al., 2002). Socio-demographic data were extracted directly from the epic system. We used the date of the surgery as a reference date between presurgery and postsurgery. The type of surgery was classified as: 1) laminotomy, 2) laminectomy, or 3) arthrodesis (fusion) with or without laminotomy, or laminectomy. Information about physician's diagnosis and impression of the cause of low back pain before the surgery was obtained.

We selected the closest presurgery complete blood count (CBC) lab tests (at most 2 weeks before the surgery) to indicate presurgical hemoglobin and hematocrit levels. We selected the CBC test taken one day after the surgery to indicate postsurgical hemoglobin and hematocrit levels. The total volume of fluid resuscitation was calculated as sum of the volumes of crystalloids and colloid.

We accessed PT inpatient flowsheets from the electronic medical record system to extract PT assessment and treatment data, and physical therapists' documentations to identify patients' home type, living situation, and prior level of function (PLOF). PLOF was determined based on the level of assistance needed in mobility and activities of daily livings as reported by patient (fully independent, independent in community with limitation, and independent at household level with or without assistance). In PT flowsheets, postoperative functional dependency score was evaluated by the 8-points functional independence measure (FIM) scale (Hamilton B, 1987). The scale minimum score is 1 as total assistance, and maximum score is 7 as complete independent. Score for level of dependency in bed mobility and transfer were added as one combined score (dependency score). Gait distance in feet and the level of assistance needed (measured by FIM also) during gait training (gait assistance) were collected. Balance was assessed based on 11-point (the higher the score the higher the balance) KU hospital balance scale (Kluding, Swafford, Cagle, & Gajewski, 2006). Sitting and standing balance were averaged to one combined score (balance score).

We extracted LOS information from UHC CDB data within HERON. Data related to comorbidities, complications, severity of illness, admission day of the week, and intensive care units length of stay (ICU (LOS)) were obtained from the UHC DCB billing records. The All Patient Refined-Diagnosis Related Group (APR-DRG) severity of illness was calculated based

on primary and secondary discharge diagnoses, age, and preexisting medical conditions (Iezzoni et al., 1995). Severity of illness is rated as minor, moderate, major, and severe. Comorbidities were any of these conditions: cerebrovascular disease, chronic pulmonary disease, cardiovascular disorders , connective tissue disease, dementia, hemiplegia, leukemia, malignant lymphoma, myocardial infarction, peripheral vascular disease, ulcer disease, endocrine disorders, liver disease, renal disease, malignant solid tumor, depression, anemia, obesity, fluid and electrolytes disorders, psychosis, alcohol and drug abuse (Laws & Colon, 2012). Complications were any of these conditions: acute myocardial infarction, nosocomial pneumonia, sepsis, wound infection, implant or graft complication, aspiration pneumonia, and GI hemorrhage. We used number of comorbidities and complications as covariates.

Data management and statistical analysis

Categorical variables were examined and converted into dummy-coded variables. Assumptions for multivariate analysis were tested. We also tested for the univariate normality distribution of continuous variables and performed transformation to the variables whenever needed (square root transformation for gait distance). LOS was not normally distributed, however it was transformed using natural log to reduce the univariate skewness and kurtosis (Ln (LOS)) (Gao, Mokhtarian, & Johnston, 2008). Univariate outliers were screened using Q-Q plots, and multivariate outliers were investigated using Mahalanobis d-squared distance (Barnett & Lewis, 1994). Random single univariate outliers were removed. In the event of multivariate outliers, the whole case was removed. The multivariate normality distribution of the model was tested using Mardia's coefficient (Mardia, 1970).

We used SPSS 20.0 (SPSS Inc. Chicago, IL) for descriptive statistics and correlational analysis. SPSS Amos 20.0 (SPSS Inc. Chicago, IL) was used for SEM analysis. The SEM

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consisted of Ln (LOS) as the dependent variable to be regressed on three latent factors indicated by multiple manifest (indicator) variables as following:

1. **Presurgical factor**: Age, sex, race, ethnicity, body mass index (BMI), marital status, living situation, type of home, use of assistive devices, PLOF, hemoglobin and hematocrit levels before, and number of comorbidities.

2. **Surgical factor**: Type of surgery, previous LSS, admission day of the week, diagnosis, severity of illness, ICU (LOS), complications, and total volume of fluid resuscitation.

3. **Postsurgical factor:** Gait distance, gait assistance, bed mobility and transfer combined dependency score, balance score, hemoglobin and hematocrit levels after surgery, postoperative pain intensity, and pain location.

We used the maximum likelihood method to estimate the parameters. We estimated loadings and modification indices to examine the best indicators of the latent variables, and to determine which variable should be dropped prior to SEM testing (Schreiber, Nora, Stagec, Barlowb, & Kinga, 2006). Variables that generated loading less than 0.3 standardized estimates (λ of composite scores of the manifest variables) were dropped from the latent variables. The overall reliability of the factor is indicated by an alpha coefficient >0.7. We set the threshold of modification indices at 4.0. Variables with high modification indices that could not be lowered by covariating with other variables and variables that generated high standard residual covariance were dropped from the model.

Chi-square statistics was used to evaluate the absolute overall fit of the model to the data. For this test if the p-value was <0.05, the model was rejected (Hua & Bentler, 1999). Several relative fit tests were also used for goodness-of-fit analysis including: 1) Goodness of Fit Index (GFI), 2) Normed Fit Index (NFI), 3) Comparative Fit Index (CFI), and 4) the root mean squared error of

approximation (RMSEA) (Bollen & Curran, 2005). To conclude goodness-of-fit, NFI and CFI

should be >0.9 (Kline, 2005), and RMSEA should be ≤ 0.06 (Brown, 2006), and GFI>0.95

(Schreiber, et al., 2006).

The LOS variable was not normally distributed even after the natural log transformation.

Most of patients were discharged in the first 3 days following surgery, and less number of

subjects stayed beyond 3 days. Therefore, skewness of LOS is expected and represents real-

world data. However, this might affect the accuracy of the parameter estimates; therefore, we

pursued bootstrapping technique to test the effect of non-normality on our SEM results.

Bootstrapping technique was completed by resampling our cohort with replacement to 2000

samples in Amos and we used Bollen-Stine p-value to assess the fitness of the model. We

reported the estimates, standard errors, confidence intervals, and significance (p<0.05) results

from bootstrapping analysis.

2.4 Results

After receiving the data file of 601 medical records, we started the data mining process.

Eight cases were deleted as multivariate outliers, resulting in 593 cases. Table 1 shows the

summary of the covariates of the 593 cases. Only original data set from the medical records was

used in the analysis without replacing random missing variables.

Appendices A, B and C show the correlation matrices using simple correlation analysis

between all covariates. LOS was significantly correlated with all variables except pain intensity,

admission day of the week, ethnicity, marital status, and previous spine surgery. These variables

were not considered in constructing the SEM.

LOS was positively correlated with ICU (LOS), age, total volume of fluids resuscitation, and negatively correlated with hemoglobin and hematocrit levels before and after surgery, dependency score, balance score, gait assistance score, and gait distance. Female gender, non-white race, living alone, living in apartment rather than house, more dependent PLOF, fusion rather than laminectomy and laminotomy, and patients with spondylosis and high illness severity, pain radiating into lower extremities, and more comorbidities or complications were associated with longer LOS.

Several variables generated low loading and were removed from the model. Inspection of the modification indices indicated covariating age with PLOF, gait assistance with dependency score, and covariating the three latent factors (Figure 1). Figure 1 shows the final SEM constructed from the 3 latent variables: presurgical, surgical, and postsurgical. Test of absolute fit showed that the model fits the data ($\chi 2(47) = 63.49$, $p = 0.085$). Using relative fit tests, NFI=0.97, IFI=0.99, CFI= 0.99, and RMSEA= 0.02 (90% CI=0.00 − 0.04), we can also conclude that the model relatively fits the data (Hua & Bentler, 1999). Table 2 demonstrates the correlation between all covariates that were used to constructor the final model.

The Mardia's coefficient of multivariate kurtosis was 2.97, indicating significant kurtosis and non-normal distribution, yet had minimal impact on model goodness-of-fit. Due to skewed distribution of the data, we chose to bootstrap the maximum likelihood estimates for the non-normal data by resampling our cohort to 2000 random samples in Amos. Bootstrapping showed Bollen-Stine p-value of 0.24 which agrees with our results of goodness-of-fit based on normality assumption.

The model posited that presurgical, surgical, and postsurgical factors have significant direct effects on the Ln (LOS) (Table 3). The indicators (manifest) variables have also significant direct effects on the latent factors (Table 3).

Unstandardized effects

Presurgical

The direct effect of the presurgical factor on Ln (LOS) was 0.18 (*p*=0.04, 95% CI= 0.01 – 0.32), which is equal to 1.19 (95% CI=1.01– 1.38) on LOS. Due to this direct effect, when the presurgical factors increased by one unit, the LOS increased by 1.19 times.

Hemoglobin level had a negative direct effect on the presurgical factors that was equal to -1.04 (p=0.001, 95% CI= -1.36 – -0.78). Consequently, when the presurgical factor decreased by one unit, the hemoglobin level increased by 1.041gm/dl. Age also had a positive direct effect of 18.74 on presurgical factor (p=0.001, 95% CI = 15.13 – 23.99). When the presurgical factor increased by one unit, the age increased by 18.738. Finally, the direct effect of PLOF on presurgical factor was -1.16 (p=0.001, 95% CI = -1.44 – -0.91). If the presurgical factors increased by one unit, the patient level of function before the surgery decreased by 1.04 (became more dependent).

Surgical

The direct effect of the surgical factor on Ln (LOS) was 0.36 (p=0.001, 95% CI=.15 – .64), which is equal to 1.44 (95% CI=1.16 – 1.44) on LOS, indicating that when the surgical factors increased by one unit, LOS increased by 1.44 times.

The direct effect of surgical factor on complications was 0.13 (p=0.001, 95% CI=.05 – .29), and on ICU (LOS) was 0.20 (p =0.001, 95% CI=.10 – .41). If the presurgical factors increased by one unit, the number of complications increased by 0.13, and ICU (LOS) increased by 0.20.

Postsurgical

The direct effect of the postsurgical factor on Ln (LOS) was -0.08 (p=0.001, 95%CI = -0.09 – - 0.06), which is equal to -1.08(95% CI=1.10 – 1.06). When the postsurgical factor increased by one unit, the LOS decreased slightly, by 1.08 times.

The direct effect of postsurgical factors on gait assistance, dependency score, and balance score were 0.12, 0.36, 0.33 (p=0.001, 95% CI = 0.10 – 0.14, 0.33 – 0.42, 0.30 – 0.37) consequently. These results showed that if postsurgical factor increased by one unit, the assistance required during walking decreased by 0.12, the assistance required for bed mobility and transfer (dependency score) decreased by 0.36, and sitting and standing balance scores increased by 0.33.

Standardized effects

Standardized effects of the latent variables (Fig. 1) showed that postsurgical factors was the most influential factors on the variation in LOS (standardized estimates = -0.50, 95% CI = -0.58 – -0.41, p=0.001), then surgical factor (standardized estimates = .21, 95% CI = .11 – .32, p=0.001), and the least was presurgical factors LOS (standardized estimates = .13, 95% CI = 0.01 – 0.23, p=0.03).

Variability in the LOS

The 3 latent factors explained 47% of the variation in the LOS (Fig. 2). Variation partitioning showed that postsurgical factors consumed by far the strongest independent effect on LOS, accounting for 19% of the explained variance. In comparison, independent presurgical (1%) and surgical (4%) effects were weak. The common area indicates that 23% of the variation in LOS could be explained by at least two factors together.

Correlation and covariance

There are significant (p=0.001) correlation and covariance between the three latent variables (Table 4). There is strong negative relationship between presurgical and postsurgical factor (r=$-$.53), moderate positive relationship between presurgical and surgical factor (r=.38), and less moderately negative relationship between surgical and postsurgical factor (r=.32). Postsurgical factor had strong negative correlation with presurgical factor, and moderate negative correlation with surgical factors. Meanwhile, the covariance between presurgical and surgical factor indicated they are almost independent.

2.5 Discussion

This study retrospectively identified factors predictive of LOS following LSS of laminotomy, laminectomy, and fusion. We constructed a SEM to categorize numerous indicator variables correlated with LOS to three latent factors: presurgical, surgical, and postsurgical factors. The three factors were correlated and had shared variability in predicting LOS. Our final model showed that age, PLOF, use of assistive devices, and preoperative hemoglobin levels were the indicators of presurgical factors. Severity of illness, ICU (LOS) and postoperative

complications were the indicators of surgical factors. Gait distance and assistance, dependency score, and balance were the indicator of postsurgical factors. The 3 factors had significant direct effect on LOS and explained 47% of the variation in LOS. We found that 23% of the variations were shared between at least two of the 3 factors, whereas 24% variation was independent to each of the three factors contributing to the LOS. Statistical models presented in this work suggest that postsurgical factors were the strongest predictors of LOS.

Ethnicities, BMI, marital status, pain intensity and admission day of the week were not significantly correlated with LOS. Other studies have also indicated no correlations between LOS, and ethnicity and BMI (Becker, et al., 2010; Epps, 2004; Escalante, 1997; Forrest, G., et al., 1998). Pain intensity recorded during the acute period may be masked by the type and the dose of analgesics resulting in inaccurate assessment of pain intensity (Harvey & Kallmes, 2011; Neatherlin, et al., 1988). Admission day of the week affected the LOS following joint replacement surgeries, but this finding is affected by patients' activity level on weekends and the availability of physical therapists (Husted, et al., 2008). Although having previous LSS and marital status have been shown to affect LOS in many similar studies (Deyo, et al., 2010; Husted, et al., 2008), in our sample these variables were not correlated with LOS.

Sex, race, living situation, type of home, hematocrit levels before surgery, number of comorbidities, type of surgery, diagnosis, and total volume of fluid resuscitation, hemoglobin and hematocrit levels after surgery, and postoperative pain location were significantly correlated with LOS. However, these variables were dropped out of the final SEM, possibly due to their modest effect and collinearity with other variables. Our findings are similar to previous studies in which, race and sex were shown to be correlated but correlation was not significant (Arnold, et al., 2011; Husted, et al., 2008; Sharma, et al., 2012), or had modest significant effect on LOS

(Deyo, et al., 2010). Similarly, living situation and type of home have shown to be correlated with LOS, but not significant predictors (Epps, 2004; Kelly & Ackerman, 1999). Hematocrit level before surgery had strong correlation with hemoglobin; by default, one of these factors had to be dropped from the model. Hematocrit and hemoglobin level after surgery and total volume of fluid resuscitation were only correlated with LOS, but were not significant predictors in our study or a previous LSS study (Zheng, et al., 2002). In addition, these variables had collinearity effects among each other as well as with presurgical hemoglobin levels.

Comorbidities have shown to be significant predictors in previous studies (Deyo, et al., 2010; Husted, et al., 2008), but this construct was dropped from our model. The significant effect of comorbidities on LOS may have been washed out by inclusion of age in the statistical model, as older age and greater number of comorbidities are linked to a longer period of LOS. Secondly, the types of comorbidities might have different influence on LOS, such as the presence of diabetes was the only comorbidity as the significant predictor of LOS in people who had joint replacement surgery (Forrest, G., et al., 1998).

LOS is a highly complex topic with numerous measurable and intangible factors. Previous studies examining LOS following LSS are limited to small sample size and limited number of factors (Nahtomi-Shick, et al., 2001; Sharma, et al., 2012; Zheng, et al., 2002). The SEM models presented in this study accounted for many possible factors that were not considered before as potential predictors of LOS following LSS, but were included in models of other orthopedic surgeries such as cervical spine surgeries and total knee and hip arthroplasties (Arnold, et al., 2011; BuSaba & Schaumberg, 2007; Epps, 2004; Husted, et al., 2008; Schneider, et al., 2009). By examining all possible variables related to presurgical, surgical, and postsurgical, we identified factors that were most likely to predict LOS.

Our results showed that as patient's age increases, and the level of hemoglobin and PLOF decreases, and the probability for the patient to stay longer in hospital increases. Presurgical factors have been extensively utilized to predict LSS outcomes in previous studies, but the unique variability explained by presurgical factors in our study was very limited.

In previous studies age was associated with LOS in most of the LSS studies (Jo, et al., 2010; Neatherlin, et al., 1988; Sharma, et al., 2012), and even in similar orthopedic surgeries (Nahtomi-Shick, et al., 2001; Zheng, et al., 2002). Increased age was found to be a predictor of LOS and the LOS was significantly different between different age groups. Jo et al., (Jo, et al., 2010) reported significant difference in LOS between patients older than 65 in comparison to younger patients who underwent lumbar fusion. Increased age is always linked with longer LOS period due to greater numbers of comorbidities and higher rate of complications following surgery. Kilinçer and colleagues (Kilincer, et al., 2005) studied the effect of age on the outcomes of posterior lumbar fusion surgery: a significant difference in LOS was found between older age group (>65) in comparison with the younger age group (<65), but no difference was found in increased complications, estimated blood loss, and operative time.

Although, PLOF and use of assistive device are parts of routine assessment for patients being admitted to hospital, they have rarely been used as predictors of LOS following LSS. Preoperative use of walking aids was a significant predictor of LOS after total joint replacement surgeries (Husted, et al., 2008). PLOF has been used previously in only one LSS study but it was combined with postsurgical dependency scores (Sharma, et al., 2012), which limited the predictive estimates of PLOF along. Use of assistive devices and PLOF reflect patients' functional ability before the surgery. These are modifiable factors and could be improved by rehabilitation to optimize surgery outcomes. Patients who received rehabilitation before and

immediately after surgery had significant reduction in LOS following LSS in comparison to subjects who received rehabilitation after surgery only (Nielsen, et al., 2010). Finally, preoperative hemoglobin is a significant predictor in our study, which contradicts a previous finding in a similar LSS study (Zheng, et al., 2002). However, Zheng et al., (Zheng, et al., 2002) included patients with revision surgeries only, whereas our sample had patients with primary and revision surgeries.

Our results showed a positive correlation between presence of complications and longer stay at ICU, and the total Ln LOS. Greater number of complications results in longer stay in ICU, which ultimately leads to longer LOS in hospital.

Severity is an indicator of patient's medical status and need for clinical supervision. Severity of the illness is usually calculated based on age, number of comorbidities, and primary and secondary diagnoses upon discharge. Severity of illness may affect patient's progress toward recovery and require greater needs for clinical supervision, and therefore longer stay in the hospital. Severity of illness had stronger correlation with comorbidity than age (see appendix); this may explain why comorbidities variable was dropped from the SEM, but age was not.

Surgical complications is one of the most common factors that was reported to affect the LOS in spine surgeries (Clarke & Rosen, 2001; Deyo, et al., 1992; Kilincer, et al., 2005), and other surgeries (Arnold, et al., 2011; BuSaba & Schaumberg, 2007; Epps, 2004). In our study, the percentage of patients who had complications was relatively low in comparison to other studies. Smith et al., (Smith et al., 2010) reported 7% of 10,329 of patients experienced surgical complications following lumbar decompression surgery between 2004 and 2007. With recent advances in spine surgery, these figures are likely to decrease and result in reducing LOS.

ICU (LOS) is rarely studied as predictor of total LOS. Becker and colleagues (Becker, et al., 2010) reported that patients who had trauma in different body parts due to falls and needed ICU stay were significantly less likely to be discharged to home. Thus, patients needing ICU may have poor functional status and require higher need for medical care in comparison to those who are not admitted to the ICU. Nahtomi-shick et al., (Nahtomi-Shick, et al., 2001) reported that ASA, physical status, surgical procedure, volume of fluid transfused, and age were significant predictors for ICU (LOS) following LSS.

Postsurgical factor studied showed that patients needing less assistance during walking, bed mobility, and transfer (dependency score), and those who had higher balance score, their function was better, and they had shorter LOS in hospital.

Postsurgical factor are rarely used to predict LOS, especially the PT assessment variables. Our results show that postsurgical factors would be significant predictors and can uniquely explain 19% of the variation in predicting LOS. Our findings suggest the importance of PT assessment as it was the only postsurgical indicators remained to be significant predictor in the model. Functional dependency score was reported to be a predictor of LOS following LSS (Sharma, et al., 2012). In our study the gait distance and balance were used as predictors of LOS. Ability to walk and walking distance have been reported to predict discharge destination following total hip replacement (de Pablo, et al., 2004; Félix & Fritzsche, 2004) and our study following LSS (manuscript in review), while balance, to our knowledge, was not reported before in similar studies.

One of the important features of this study is that we analyzed factors for correlation, covariance and shared variability. Our study showed that presurgical, surgical, and postsurgical factors have shared variability in explaining LOS. Postsurgical factors, which were constructed

from PT assessment variables, appeared to have the highest independent variability, where other factors explained relatively little variability to LOS. This highlights the importance of the documentation of PT assessment variables and consideration these factors in discharge planning. Presurgical factors showed to have the least independent variability because presurgical factor had strong covariation with postsurgical factors and weak covariance with surgical factors. It could be argued that presurgical factors can be dropped from the model of predicting LOS, whenever postsurgical factors are available.

The payment factor is influential on LOS: the health care service payers have strong influence on LOS decision. Patients treated under health maintenance organizations have significantly shorter times in hospital than those treated under fee-for-service plans (Bradbury, et al., 1991; Clarke, 1996). Also, the quality and type of community care (e.g. family assist, or home health) may influence the discharge planning and LOS. Generalizability of our prediction models would have some limitations: 1) this is a retrospective study with few missing data, 2) the assessment was conducted by many healthcare professionals and may not be well standardized, 3) the data are taken from one healthcare center, therefore it should be taken in consideration the difference in practice between regions and health centers in the same region (Weinstein, J. N., et al., 2006).

2.6 Conclusion

LOS is multifaceted and prediction of LOS requires accurate and comprehensive documentation and understanding of the variation in variables associated with before, during and after the surgery. Functional assessment before and after the surgery showed to be important predictors of LOS, and important modifiable factors that should be considered to improve

surgical outcomes. It is highly recommended to reproduce this study in prospective method and include standardized assessment to increase the prediction accuracy of the LOS.

Disclosure/Conflict of Interest

No duality of interest to declare.

Table 2. 1: Descriptive statistics for all the covariates extracted from 593 medical records

Variable	Mean (SD), %	N
Length of stay (days)	4.01 (2.73)	593
Age (years)	61.97 (14.49)	593
Gender		593
• Male	52.3%	
• Female	47.7%	
Race		593
• White	83.2%	
• Non-white	16.8%	
Ethnicity		593
• Non-Hispanic	97.2%	
• Hispanic	2.8%	
Marital status		593
• Married	66.0%	
• Divorced/separated/widowed/single	34.0%	
Body Mass Index (kg/m^2)	31.95 (6.59)	593
Hemoglobin before surgery (mg/dl)	13.70 (1.36)	585
Hematocrit before surgery (%)	40.35 (3.88)	586
Type of home		544
• House	91.6%	
• Apartment	6.3%	
• Other	2.1%	
Home situation		530
• Lives with family	73.8%	
• Has assistance at home	10.1%	
• Lives alone	16.1%	
Prior level of function (PLOF)		525
• Independent Mobility at Household Level with or without e/assistance	12.1%	
• Independent Mobility in Community w/ device or Endurance Limitations	27.4%	
• Independent	60.5%	
Assistive devices used		543
• None	40.0%	
• 1 or 2 points	31.0%	
• 3 or 4 points	28.9%	
Total number of comorbidities		593
• 0	45.2%	
• 1	23.2%	

• 2	15.3%	
• 3≤	16.3%	
Surgery classification		593
• Laminotomy	18.5%	
• Laminectomy alone or with laminotomy	41.8%	
• Fusion with laminotomy or laminectomy or both	39.7%	
Previous surgeries		593
• No	95.5%	
• Yes	4.5%	
Diagnosis		593
• Lumbago	11.3%	
• Spinal stenosis of lumbar region	58.4%	
• lumbosacral neuritis or radiculitis, sciatica/ lumbar intervertebral disc	29.1%	
• Lumbosacral spondylosis without myelopathy	1.2%	
Total infusion (mL)	2477.98 (1189.06)	497
Severity of illness		593
• Minor	52.2%	
• Moderate	41.6%	
• Severe	6.2%	
Admission day of the week		593
• Sunday, Monday. Tuesday, Wednesday	36.0%	
• Thurs, Friday, Saturday	57.5%	
Complication/s		593
• No	98.1%	
• Yes	1.9%	
Intensive care unit length of stay (days)		593
• 0	96.0%	
• 1	2.3%	
• 2 ≤	1.7%	
Pain intensity (0-10 pain scale)	5.19 (1.31)	593
Pain location		593
• Back only	73.8%	
• Thigh and buttock	11.1%	
• Leg and feet	15.1%	
Dependency score	9.81 (1.99)	525
Balance	6.18 (1.82)	560
Gait assistance	5.18 (0.81)	570
Gait distance	166.43 (175.75)	570
Hemoglobin after surgery (mg/dl)	11.36 (1.54)	579
Hematocrit after surgery (%)	33.35 (4.41)	583

Table 2. 2: Correlation matrices showing correlation coefficients between covariates used in the final structural equation model

	Mean (SD)	LOS	Assistive device	Hemoglobin level	Age	PLOF	Severity of illness	Complication	ICU LOS	Gait distance	Dependency
LOS	4.01(2.73)	1	--	--	--	--	--	--	--	--	--
Assistive devices	1.27(1.38)	.223‡	1	--	--	--	--	--	--	--	--
Hemoglobin level	13.70(1.36)	-.175‡	-.19‡	1	--	--	--	--	--	--	--
Age	61.97(14.49)	.24‡	.35‡	-.26‡	1	--	--	--	--	--	--
PLOF	3.40(.91)	-.32‡	-.39‡	.18‡	-.19‡	1	--	--	--	--	--
Severity of illness	.55(.64)	.32‡	.18‡	-.12‡	.15‡	-.21‡	1	--	--	--	--
Complication	.02(.14)	.23‡	-.03	-.02	.06	-.01	.28‡	1	--	--	--
ICU LOS	.07(.44)	.19‡	.05	-.07	.11*	-.17‡	.30‡	.23‡	1	--	--
Gait distance	166.43(175.8)	-.39‡	-.19‡	.20‡	-.14‡	.18‡	-.12‡	-.07	-.11‡	1	--
Dependency score	9.81(1.99)	-.47‡	-.23‡	.22‡	-.27‡	.26‡	-.21‡	-.08	-.14‡	.54‡	1
Balance score	6.18(1.82)	-.46‡	-.27‡	.20‡	-.29‡	.26‡	-.20‡	-.07	-.20*	.57‡	.69‡

‡Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed), LOS: Length of stay, PLOF: Prior level of function, ICU LOS: intensive care unit length of stay

Table 2. 3: Unstandardized estimates of the direct effects resulting from the structural equation model analysis

Measurement model	Parameter	Estimates	Bootstrap S.E.	Bias-corrected, 95% CI	p
Presurgical	Use of assistive devices	1.00			
	Hemoglobin level	-1.04	.15	-1.36 - - .78	.001
	Age	18.74	2.18	15.13 – 23.99	.001
	PLOF	-1.16	.14	-1.44 - -0.91	.001
Surgical	Severity of illness	1.0			
	Complication	.13	.06	.05 - .29	.001
	ICU LOS	.20	.08	.1 - .409	.001
Postsurgical	Sqrt (gait distance)	1.00			
	Gait assistance	.12	.01	.10 - .14	.001
	Dependency score	.36	.03	.32 - .42	.001
	Balance combined score	.33	.02	.30 - .37	.001
Structural model					
Ln (Los)	Presurgical	.18	.08	.01 - .32	.044
	Surgical	.33	.12	.149 - .64	.001
	Postsurgical	-.08	.01	-.09 - -.060	.001

PLOF: prior level of function, LOS: length of stay, ICU LOS: intensive care unit length of stay, S.E: standard error

Table 2. 4: Correlation and covariance estimates

	Correlation				Covariance			
	Estimate	S.E.	CI	p	Estimate	S.E.	CI	p
Presurgical with surgical	.38	.09	.21 - .56	.001	.08	.02	.03 - .12	.001
Presurgical with postsurgical	-.53	.05	-.62 - -.43	.001	-1.14	.14	-1.14 - -.86	.001
Surgical with postsurgical	-.32	.06	-.46 - -.21	.002	-.63	.16	-.94 - -.32	.001

S.E: standard error
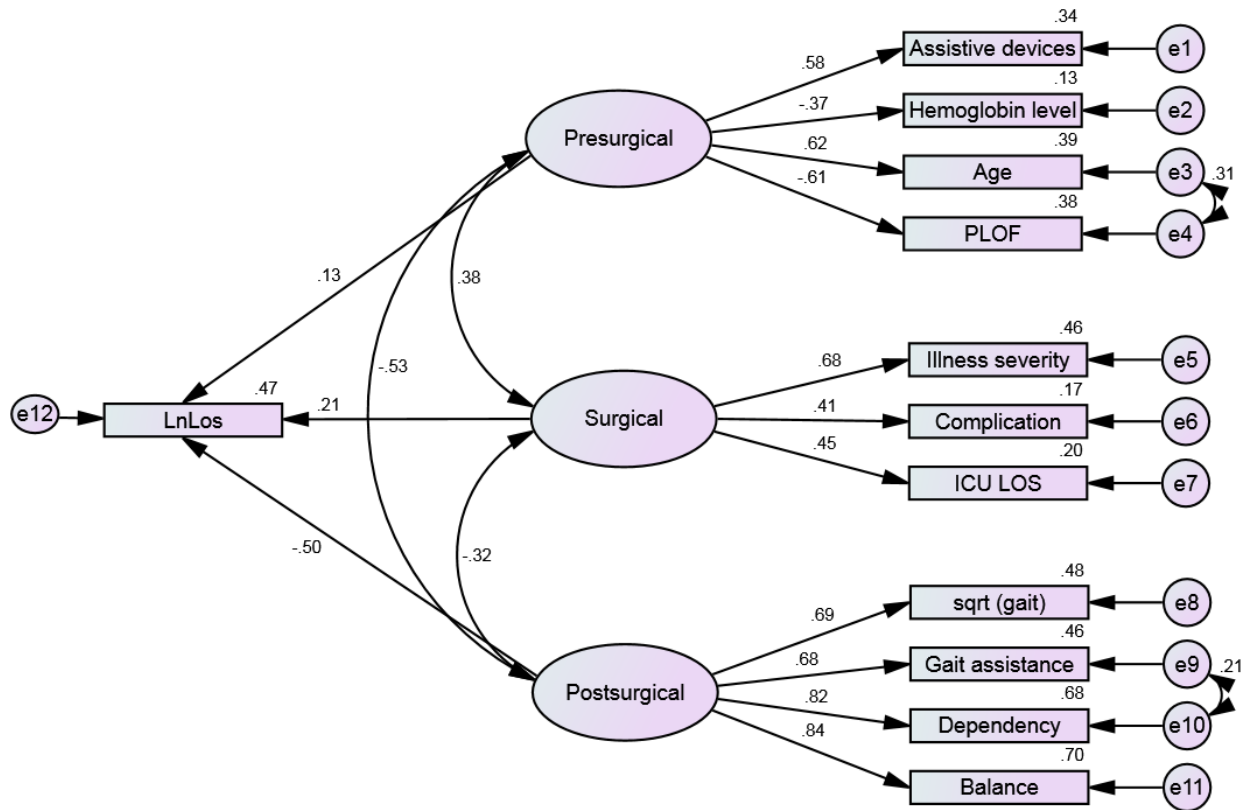
Figure 2. 1: Structural equation Model for the length of stay constructed in Amos. Quantities near paths are standardized loadings. Degrees of freedom=47, e=error. Ln LOS is the dependent variable. Variables presented in ellipse are latent factors
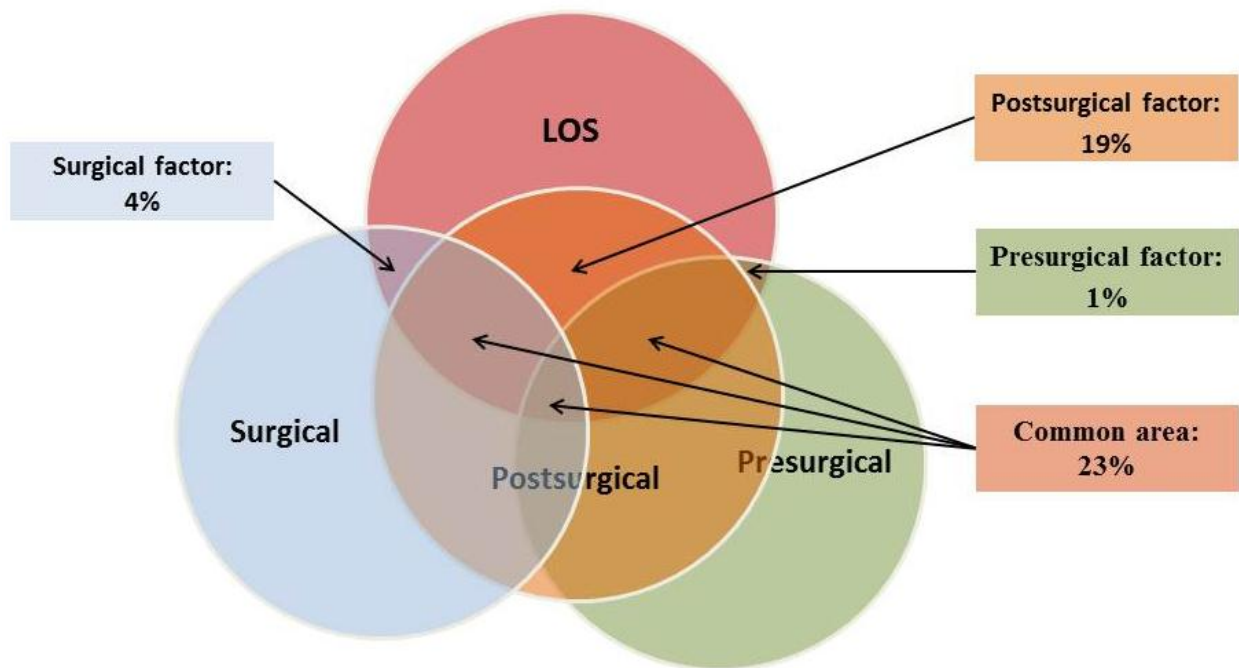
Figure 2. 2: Shared variability of the factors predicting LOS. All factors predicting 47% of LOS. Values give the % of the total variation independent and shared effects. Independent variability of presurgical =1%, surgical=4%, and postsurgical=19% as indicated by the arrows. The variability shared by the three variables (common area) =23%.

Chapter 3

Predicting Discharge Placement and Health Care Needs

After Lumbar Spine Laminectomy

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3.1 Abstract

Objective: To explore factors associated with discharge placement (DP) and need for skilled assistance after patients are discharged to home following lumbar Laminectomy

Methods: A retrospective analysis of 339 patients who underwent lumbar laminectomy was conducted. We used multivariable logistic regression analysis to identify significant covariates and to construct two regression models: a primary model to predict DP, home versus inpatient rehabilitation/skilled nursing facility (IR/SNF), and a secondary model to predict the need for skilled assistance once patients are discharged to home.

Results: Sample included 48.7% females, 68.2% married, 56.3% independent in daily activities, and 85.2% discharged to home. Subjects were 56.06±12.75 years old and had 31.35±6.2 BMI. Of those discharged to home, 17.7% needed skilled assistance. Patients stayed 4.41±3.55 days in the hospital and walked 203.38±144.87 feet during hospital stay. Age, distance walked during hospital stay, and length of hospital stay (LOS) were significant positive predictors for discharge to home versus IR/SNF, whereas single living status, diminished prior level of function, and longer LOS were predictors of need for skilled assistance after discharge to home.

Conclusion: Age, mobility, marital status, prior level of function and LOS are key variables in determining healthcare needs following lumbar Laminectomy.

Key words: Laminectomy, discharge placement, skilled care, physical therapy, functional status, length of stay.

3.2 Introduction

In the United States, there has been an increase in the prevalence of lumbar spine surgeries (LSS), with a similar increase in surgery costs and related post-surgical care.(Deyo, 2006; Schiller, et al., 2012; Weinstein, J. N., et al., 2006) The prevalence of these surgeries in the US is approximately 0.2% of the population, which is at least 40% higher than other countries and five times higher than England and Scotland.(Cherkin, et al., 1994; Gray, et al., 2006; Ostelo, et al., 2003) This rise in LSS in the last decade has increased the demands for optimizing surgical outcomes, and need to establish evidence-based guidelines for patient's health care needs during their hospital stay and after hospital discharge.(Archer et al., 2011; Chou, et al., 2009; Mannion & Elfering, 2006; Mannion, Elfering, et al., 2007)

Lumbar laminectomy is a common surgical procedure, primarily for the treatment of lumbar stenosis in elderly patients.(Gibson & Waddell, 2005) Current randomized controlled trials support lumbar laminectomy over conservative management.(Weinstein, J. N. et al., 2009) Patients who received spine surgery reported significant improvement in pain, function, and quality of life which was maintained for 4-years.(Weinstein, J. N. et al., 2008) However, the results of spinal surgeries are not always consistent and present significant variation in short and long term outcomes.(Desai, et al., 2012) Implementation of post-surgical interventions such as rehabilitation and post-surgical care may optimize surgical outcomes.(Desai, et al., 2012)

Studies have investigated possible pre- and post-surgical factors to predict short- and long-term outcomes.(Carragee, et al., 2003; DeBerard, et al., 2009; den Boer, Oostendorp, et al., 2006a; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; LaCaille, et al., 2005; Mannion, Elfering, et al., 2007; Nygaard, et al., 2000; Trief, et al., 2006) Patient-related factors such as age, gender, work status, comorbidities, preoperative pain intensity and duration, work

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status, and emotional and psychological factors (e.g. Fear of movement, anxiety, and depression), were found to be associated with post-surgical outcomes. (Carragee, et al., 2003; den Boer, Oostendorp, et al., 2006a; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Gaetani, et al., 2004; LaCaille, et al., 2005; Trief, 2000; Trief, et al., 2006)

Intraoperative factors have also been shown to influence postsurgical outcomes. Intraoperative fluid infusion, American Society of Anesthesia (ASA) score, physical status, type of surgical procedure, and total intraoperative platelet administration were significant predictors of length of stay (LOS) in an intensive care unit.(Nahtomi-Shick, et al., 2001) In another study, the number of levels fused, postoperative hemoglobin and hematocrit values, total volume of blood resuscitation, and duration of operation were also significantly correlated with LOS.(Zheng, et al., 2002) However, these variables have not been investigated for hospital discharge planning and health care needs following hospital discharge.

Inpatient physical therapy (PT) assessment plays an important role in discharge planning. However, PT assessment and functional status are rarely studied as possible predictors of short- or long-term outcomes after LSS. Sharma and colleagues(Sharma, et al., 2012) showed that LOS was significantly correlated with the number of inpatient PT encounters and pre- and post-surgical functional levels. LOS was significantly higher for patients discharged to a health care facility compared to home. Therefore, the aforementioned factors could also be associated with discharge placement (DP) after LSS and should be explored.

The process of discharge planning starts soon after surgery and is determined by interdisciplinary team members. Discharge planning is targeted to ensure efficient hospitalization and to determine appropriate DP, e.g. home versus health care facility, to bridge the gap between hospital and community care after discharge.(Shepperd, S., 2004; Shepperd, Sasha, 2009;

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Shepperd, S., et al., 2010) Recently, there has been an increased demand to shorten LOS and to provide safe and appropriate DP for continuous community care.(Shepperd, S., 2004; Shepperd, Sasha, 2009; Shepperd, S., et al., 2010) In early discharge and short hospital stays, patients are usually medically stable but might not have reached the optimal functional and independence level after discharge.(Mauerhan, 2003) Upon discharge, patients receive education and medication to manage their symptoms. However, some patients following discharge may also need longer recovery time and more assistance with daily activities, provisional to their functional and medical status.

Predictors of DP have been determined in several orthopedic surgeries such as vertebroplasty(Harvey & Kallmes, 2011) and total hip or knee replacement.(de Pablo, et al., 2004; DeJong, et al., 2011; Mallinson, 2011) Prediction models were built with age, body mass index, ability to walk,(de Pablo, et al., 2004) pre-admission living status,(de Pablo, et al., 2004; Harvey & Kallmes, 2011) and functional status upon discharge (DeJong, et al., 2011) as significant predictors of DP. However, predictors of DP following laminectomy have not been investigated. The primary aim of this retrospective study was to explore factors associated with DP (home versus health care facility) following lumbar laminectomy. The secondary aim was to investigate the factors defining the need for skilled assistance after patients are discharged to home. The role of PT assessment was also incorporated in prediction models, which has not been considered before. Understanding these factors could assist clinicians in discharge planning and the level of care needed following hospital discharge, as well as assist patients, family members and caregivers in having realistic expectations after the surgery.

3.3 Methods

We reviewed de-identified medical records of patients who underwent lumbar laminectomy at the University of Kansas Hospital between November 2007 and July 2011. The medical informatics division at the University of Kansas Medical Center has developed the Healthcare Enterprise Repository for Ontological Narration (HERON),(Waitman, Warren, Manos, & Connolly, 2011) an integrated data repository that provides researchers an access to de-identified electronic medical records from the hospital and clinics (Epic Corporation). HERON also provides access to other administrative, research, and public sources, such as the clinics' billing system (GE IDX), the University Health Consortium (UHC) (https://www.uhc.edu), tumor registries, and the Social Security Death Index. HERON's incorporation of multidisciplinary flowsheets from the electronic medical record allowed this study to evaluate vital signs and PT assessment rarely included in prior studies. We selected our cohort of interest from HERON using the i2b2 query and analysis tool,(Murphy, et al., 2010) and created our query to find the data of interest in LSS patients' medical records.

Study Cohort

Current Procedural Terminology (CPT) codes for posterior lumbar laminectomy, laminotomy, or decompression were used to identify the cohort of interest in the i2b2 query and analysis tool. Medical records from patients 18 years or older only were included in the study. Medical records were excluded for patients with neoplasm or intraspinal abscess, spinal deformity (scoliosis, kyphoscoliosis), spine fractures, surgery for vertebroplasty or congenital deformities, osteomyelitis, history of spine fractures, and cauda equina syndrome. Based on these criteria, 352 records were identified.

Data Selection

In the HERON data system, covariates were selected based on relative research and clinical experience. (Carragee, et al., 2003; de Pablo, et al., 2004; DeBerard, et al., 2009; DeJong, et al., 2011; den Boer, Oostendorp, et al., 2006a; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Gaetani, et al., 2004; Harvey & Kallmes, 2011; LaCaille, et al., 2005; Mallinson, 2011; Mannion, Elfering, et al., 2007; Nahtomi-Shick, et al., 2001; Nygaard, et al., 2000; Sharma, et al., 2012; Trief, 2000; Trief, et al., 2006; Zheng, et al., 2002) The covariates obtained from the system are summarized in Table 1.

The recommendation for DP was obtained from the discharge summary note signed by the attending physician. The recommendations included discharge to home, home with family assistance, home setting with outpatient PT, home with home health, inpatient rehabilitation, or skilled nursing facility.

We defined comorbidities as diagnosis of any of these conditions: Cerebrovascular disease, Chronic pulmonary disease, Congestive heart failure, Connective tissue disease, Dementia, Hemiplegia, Leukemia, Malignant lymphoma, Myocardial infarction, Peripheral vascular disease, Ulcer disease, Diabetes Mellitus, Liver disease, Renal Disease, and Malignant solid tumor. We calculated the changes (post-pre surgery) in both hemoglobin and hematocrit. The sum of the volume of crystalloids, colloid was used to refer as total intraoperative fluid infusion. Patient's self-reported prior level of function (PLOF) was determined based on the level of assistance needed in mobility and activities of daily livings (independent, partially dependent, and maximally dependent). During the hospital stay, the functional independence measure (FIM) scale(Hamilton B, 1987) was used to assess the level of dependency in 3 functional activities: bed mobility, transfer, and gait. The combined score of FIM was then

classified as independent, partially dependent, or maximally independent. Sitting and standing

balance scores during inpatient stay were measured with an 11-point balance scale.(Kluding, et

al., 2006) LOS was calculated as the number of days spent from the day of admission to the day

of discharge.

Data Processing

Categorical variables were converted to coded variables. For DP, ordinal data were

reduced to two categories: home versus inpatient rehabilitation/skilled nursing facility (IR/SNF).

Those discharged to home were further classified into two additional categories: 1) home with

skilled assistance (patients who needed more than family assistance such as home health, and

outpatient PT), and 2) home without skilled assistance (Figure 1).

We tested the normality of the continuous variables and performed transformation on

variables whenever necessary [natural log transformation of the LOS (ln (LOS)) and square root

transformation of gait distance (sqrt (gait)].

Statistical Analysis

PASW Statistics 20 (SPSS, Inc., 2009, Chicago, IL) was used for statistical analysis. To

test the differences between two main groups (home vs. IR/SNF) and two subgroups (home with

skilled assistance and home without skilled assistance), we used independent sample student's t-

test for normally distributed continuous variables, Mann-Whitney's test for skewed continuous

variables, and chi square rest for categorical variables ($p<0.05$). We performed univariable

logistic regression to explore important covariates ($p<0.1$) to be entered in multivariable logistic

regression models. In multivariable logistic regression models, possible predictors were removed

from the model if they did not contribute significantly to the model ($p<0.05$) using the enter selection method. Also, we used backward and forward selection methods to confirm our results. Significant variables were then used to build the final two models, home vs. IR/SNF and home with or without skilled assistance. We then used receiver operating characteristics (ROC) curve to evaluate the classification accuracy of the final models. The multivariate model was built using complete cases considering small proportions of missing values among potential predictor candidates.

3.4 Results

Of the entire data set, 14.8 % (52 patients) were discharged to IR/SNF, 67.3% (237 patients) were discharged to home without skilled assistance, and 17.9% (63 patients) were discharged to home with skilled assistance (Figure 1).

Model I: Home versus IR/SNF

The differences between patients discharged to home and patients discharged to IR/SNF are summarized in Table 2. Patients in the IR/SNF group were significantly older, had a higher drop in their hematocrit level after surgery, needed more fluid infusion during the surgery, had a greater number of comorbidities, and stayed longer in the hospital. PT assessment covariates showed that patients in the IR/SNF group were more likely to live alone, walked significantly shorter distance during their hospital stay, had lower balance scores, and were functionally more dependent before surgery and during their hospital stay. There were no significant differences between the two groups in other covariates, although marital and living status showed a trend toward significance between both groups.

Exploratory univariable logistic regression (Table 3) showed that age, marital status, living status, prior level of function (PLOF), change in hematocrit level, ln (LOS), and sqrt (gait), balance score, number of comorbidities, and dependency score might be potential predictors for building a multivariate logistic regression model for the response variable (Home vs. IR/SNF).

Multivariable logistic regression (Table 3) showed only age, sqrt (gait), and ln (LOS) were significant predictors of DP. Hosmer-Lemeshow goodness-of-fit test was non-significant (χ^2 (8) = 7.77, p = 0.56), indicating good fit of model.(Peng, Lee, & Ingersoll, 2002) The area under the ROC curve of the final model was 0.80, indicating good accuracy of the final model. A plot of odds ratios and confidence intervals suggests that the likelihood of being discharged to IR/SNF was increased by 2.42 for an every increment in natural log of LOS, and decreased by 0.83 for an increase in one square root of distance walked during the hospital stay. Although significant, the odds ratio for age was small, suggesting that the likelihood of being discharged to IR/SNF was increased by 1.04 for each one year increase in age.

Model II: Home With or Without Skilled Assistance

Of the 289 patients discharged to home, 229 did not need skilled assistance, while 60 needed skilled assistance (home health or outpatient PT). The differences between the two groups are summarized in Table 4. Patients who needed skilled assistance were significantly more likely to be single, required more fluid resuscitation during the surgery, had more comorbidities, and stayed longer in the hospital. Living status and hematocrit levels were not significantly different between both subgroups but showed a trend toward difference. PT assessment covariates showed that patients who needed skilled assistance were significantly

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more dependent before surgery (decreased PLOF) and during their hospital stay (decreased dependency score), walked shorter distance, and had lower balance score during their hospital stay. There was no significant difference in other covariates between the two groups.

Exploratory univariable logistic regression (Table 5) showed that age, marital status, PLOF, change in hematocrit level, ln (LOS), sqrt (gait), use of assistive devices, balance score, total intraoperative fluid infusion, number of comorbidities, and dependency score were possible predictors (p<0.1), and were entered into the multivariable logistic regression analysis.

Multivariable logistic regression (Table 5) showed that marital status, PLOF, and ln (LOS) were the only significant predictors showing which patients would need skilled assistance and which patients would not after hospital discharge. Hosmer-Lemeshow goodness-of-fit test was non-significant ($\chi2$ (8) = 2.90, p = 0.89), indicating good fit of model.(Peng, et al., 2002) The area under the ROC curve of the final model was 0.84, indicating good accuracy of the final model. A plot of odds ratios and confidence intervals (Figure 3) indicates that the likelihood of needing assistance is increased by 2.33 times for single patients as compared to married patients, and by 4.3 times for an increase in one natural log of LOS, and decreased by 0.63 times in more independent patients.

3.5 Discussion

In this retrospective study, we used multivariable logistic regression to build prediction models describing which patients might be discharged to home or to IR/SNF, and which patients are likely to require skilled assistance once discharged to home. Of the factors associated with discharge destination, only age, distance walked during hospital stay and LOS were significant predictors of DP. The ROC analysis suggests that our model is useful in determining which

patients will need IR/SNF. For the patients who required skilled assistance at home, only marital status, PLOF, and LOS were significant predictors for health care need beyond the hospital stay. The ROC analysis suggests that our model is accurate in predicting level of assistance needed following discharge to home—with or without skilled assistance. Because the study was a retrospective analysis and had multiple missing data, the generalization of our results may be limited.

Home versus IR/SNF

Our results are consistent with those of previous studies involving orthopedic surgeries of other joints, where older age has been associated with discharge to IR/SNF.(de Pablo, et al., 2004; Forrest, G., et al., 1998; Jones, Voaklander, Johnston, & Suarez-Almazor, 2001; Munin, et al., 1995) Elderly patients are more likely to be discharged to IR/SNF, because age is often accompanied by a higher rate of complications and comorbidities, as well as a longer recovery time after surgery.(DeJong, et al., 2011; Zheng, et al., 2002) In fact, declining physical function is consistent with older age. The ability to walk a longer distance during the hospital stay is considered an important positive indicator of patients' functional status and level of independence. With primary and revised total hip replacements, the patients' inability to walk at the time of hospital discharge was shown to be a significant predictor for discharge to a rehabilitation facility.(de Pablo, et al., 2004) Our results are in agreement with these findings and suggest that patients should be walking more during their hospital stay post-LSS. At present, patients' mobility is limited to the number of PT visits they receive during their hospital stay. Increasing walking distance, especially for elderly patients, may be beneficial. In our study, the LOS was also strongly correlated with the number of PT encounters (Spearman r=0.91,

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p<0.001), suggesting that patients who stayed longer in the hospital needed more PT assistance and therefore were anticipated to benefit from IR/SNF services. Financial factors and health insurance coverage are also important determinants for DP,(FitzGerald, Boscardin, Hahn, & Ettner, 2007; Lim, et al., 2007) and should be considered in future studies.

Social factors such as marital and living status, pre- and post-surgical functional status, and change in hematocrit level were associated (although were not significant predictors) with DP, and should be considered in discharge planning. Although higher BMI and female gender were associated with discharge to IR/SNF in other orthopedic studies, (de Pablo, et al., 2004; DeJong, et al., 2011) they were not significantly associated with DP in our study. However, in a previous study, only female gender, but not BMI, was significantly correlated with longer LOS after LSS.(Sharma, et al., 2012) Other socio-demographic factors, such as education level, income, and race, should be investigated as possible predictors for DP in future studies, as they were associated with DP in total hip or knee replacement surgeries. (de Pablo, et al., 2004; DeJong, et al., 2011)

Home With or Without Skilled Assistance

The amount of social support available to patients is often considered a criterion upon discharge to home with or without skilled assistance. As expected, our results suggested that unmarried patients are likely to need skilled care at home. Secondly, the PLOF was a significant predictor for skilled assistance at home. Patients with poor PLOF before surgery are not expected to show immediate improvement after surgery, and further deterioration in the functional level is expected after surgery due to the operation and hospital admission. Therefore, those patients are more likely to need assistance at home after discharge. These results are relatively similar to

Harvey and Kallames's study(Harvey & Kallmes, 2011) in which the PLOF and living status prior to surgery guided the discharge planning after vertebroplasty. Attempts to improve PLOF before spinal surgeries might result in less skilled care after hospital discharge. LOS was also a significant predictor for patients needing skilled care after being discharged to home. Longer LOS indicates a longer period of recovery and a greater need for health care services after surgery, either through IR/SNF placement or home–based skilled care, as the patients' health and functional status may not be adequate for independent function. Neither our results nor those of Harvey and Kallames'(Harvey & Kallmes, 2011) found an association between pain intensity and DP, or need for skilled care at home. Pain intensity is influenced by medication use and does not seem to be a sensitive measure; rather, physical and functional status are better guides for discharge planning.

The current study revealed an association between change in hematocrit level and DP, and between volume of blood transfusion and level of assistance needed at home; however, these factors were not significant predictors in our two models. Zheng et al., (Zheng, et al., 2002) found no correlation between blood loss and transfusion with LOS in patients who underwent lumbar spine fusion revision. Previous studies have shown correlation between intraoperative factors and LOS, but not with DP following LSS. Factors such as type of surgical procedure, ASA, and volume of intraoperative fluid infusion were predictors of LOS in an intensive care unit after mixed (cervical, thoracic, and lumbar) spine surgeries.(Nahtomi-Shick, et al., 2001) In a similar study, the surgery type was associated with, but not a significant predictor of LOS.(Sharma, et al., 2012) Surgery type did not show an association with DP in our cohort, most likely due to a fewer number of fusion surgeries.

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Previous studies have shown the importance of social and clinical factors as predictors of LSS outcomes, but our study highlighted the importance of factors determined by PT assessment as possible predictors of DP and the need for skilled care at home. PLOF, distance walked, balance, and functional dependency status are standard measures of PT assessment. PLOF is usually collected soon after hospital admission or surgery, and is used as indicator of possible rehabilitation needs. PLOF is also used to monitor patients' progress or decline in function due to hospitalization, especially in older adults.(Kuisma, 2002) The present study showed that patients who needed assistance with activities of daily livings prior to surgery were more likely to require skilled assistance after discharge, emphasizing the need to assess patients' functional status prior to surgery. Secondly, walking distance is often measured and recorded during each PT visit starting with the first post-operative day, and whenever patients receive PT services. The length of distance walked indicates the patients' ability to balance and their level of independence and endurance. Finally, dependency score measured during the PT assessment has also been considered a predictor for LOS after LSS in the Sharma et al.(Sharma, et al., 2012) study; in the present study, it was associated with DP but was not a significant predictor. De Pablo et al.(de Pablo, et al., 2004) concluded that patients who had poor functional status after total hip replacement were discharged to IR/SNF. Our results also show that patients with a poor dependency score stayed longer in the hospital and were more likely to be discharged to IR/SNF.

3.6 Conclusion

Age, distance walked during the hospital stay, and LOS were significant predictors of DP, whereas single living status, PLOF, and LOS were significant predictors of skilled assistance

upon discharge to home. Of the myriad of factors considered for DP following lumbar laminectomy, these variables appeared to be the most important. Age and the stability of patients' medical status after surgery seem to be key factors in determining DP; the LOS required to reach this level and the functional measures to assess this level are important variables. Patients' pre- and post-surgical functional status was also a significant predictor in both models. This study also suggests the importance of social support from a spouse. Incorporating the spouse and other family members in patients' management may reduce the cost and demands on health care. This study also highlights the significance of PT assessment in determining health care services following LSS, although the DP and level of assistance needed at home after discharge are decisions of the multidisciplinary team. The value of social support and PT assessment variables suggests future health service research studies may benefit from supplementing analysis that usually incorporates administrative, laboratory, and physician documentation with the increasingly rich social history and multidisciplinary assessment data available now in electronic medical record flowsheets.

Disclosure/Conflict of Interest

No duality of interest to declare.

Table 3. 1: Summary of all covariates

Characteristics	Mean (SD)	Percentage (%)	Number of valid cases
Age	56.06 (12.75)	-	317
Body mass index (BMI)	31.35 (6.23)	-	352
Gender	-		352
• Male		51.3	
• Female		48.7	
Housing	-		348
• House		88.5	
• Apartment		11.4	
Marital status	-		348
• Married		68.2	
• Single/divorced/widowed		31.8	
Living status	-		351
• Living with family or significant other		84.7	
• Not living with family		15.3	
Number of comorbidities	1.39 (1.78)	-	352
Change in hemoglobin level (gm/dl)	-1.77 (1.28)	-	331
Change in hematocrit level (%)	-2.19 (5.86)	-	335
Total fluid transfusion (ml)	2280.98 (1038.89)	-	352
Prior level of function (PLOF)	-		352
• Dependent		3.8	
• Partially dependent		39.9	
• Independent		56.3	
Inpatient back pain on numeric pain rating scale	4.50 (1.14)	-	322
Radiculopathy continued after surgery	-		283
• Yes		38.1	
• No		61.9	
Functional dependency score			352
• Independent		22.0	
• Partially dependent		48.5	
• Maximally independent		29.5	
Sitting and standing balance combined score	6.24 (1.83)	-	314
Gait distance (feet)	203.38 (144.87)	-	352
Use of assistive device during inpatient ambulation	-		
• Yes		62.6	
• No		37.5	

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Length of hospital stay	4.41 (3.55)	352

Table 3. 2: Summary of patients discharged to home vs. IR/SNF

Variable		Home mean (SD) or %	IR/SNF mean (SD) or %	p
N		289	50	
Age (years)		54.96 (12.23)	62.31 (14.01)	**<0.001***
Gender	Female (%)	48.7%	54%	0.251†
	Male (%)	51.3%	46%	
Marital status	Married (%)	70%	58%	0.052†
	Single/Divorced/ Widowed (%)	30%	42%	
BMI (kg/m^2)		31.34 (6.15)	31.39 (6.73)	0.95*
Housing	House (%)	91%	84%	0.12†
	Other (%)	9%	16%	
Living status	Family (%)	87%	74%	**0.02†**
	Other (%)	13%	26%	
Prior level of function (PLOF)	Dependent (%)	2%	14%	**<0.001†**
	Partially dependent (%)	37.8%	52%	
	Independent (%)	60.2%	34%	
Change in hemoglobin level (gm/dl)		-1.73 (1.22)	-2.01 (1.60)	0.14*
Change in hematocrit level (%)		-1.77 (5.79)	-4.62 (5.77)	**0.01***
LOS (days)		3.91 (3.20)	7.30 (4.10)	**<0.001‡**
Gait distance (feet)		223.68 (142.84)	86.05 (91.45)	**<0.001‡**
Balance score (Sitting and standing balance)		6.43 (1.78)	5.23 (1.76)	**<0.001‡**
Dependency	Independent	15.2%	6%	**<0.001***
	Partially dependent	44.9%	24%	
	Maximum independent	39.9%	70%	
Total fluid transfusion		2233.12 (1002.22)	2493.57 (1221.12)	**<0.001***
Pain Day 0		4.61 (1.11)	4.34 (1.52)	0.12*
Pain Day 1		4.54 (1.12)	4.29 (1.24)	0.20*
Radiculopathy	Yes	61%	52%	0.31†
	No	36%	48	
Comorbidities		1.25 (1.68)	2.15 (2.10)	**<0.001‡**

Table 3. 3: Univariable and multivariable logistic regression analyses for home vs. IR/SNF

Factor	Univariable analysis			Multivariable analysis		
	β	SE	*p*	β	SE	*p*
Age	0.05	0.15	**<0.001**	0.04	0.013	**0.02**
Marital status	0.61	0.27	**0.05**	‡		
Gender	-0.25	0.26	0.42	‡		
BMI	0.01	0.02	0.95	‡		
Housing	0.62	0.42	0.16	‡		
Living status	0.84	0.23	**0.02**	0.60	0.45	0.19
PLOF	-1.09	0.16	**<0.001**	-0.33	0.33	0.33
Change in hemoglobin level	-0.17	0.11	0.16	‡		
Change in hematocrit level	-0.10	0.02	**0.01**	-0.02	0.04	0.54
ln (LOS)	1.80	0.19	**<0.001**	-0.25	0.04	**<0.001**
sqrt (Gait)	-0.23	0.03	**<0.001**	0.84	0.30	**0.01**
Assistive device	0.29	0.18	0.13	‡		
Balance Score	-0.35	0.09	**<0.01**	0.02	0.12	0.88
Intraoperative fluid infusion (mL)	0.00	0.00	0.18	‡		
Pain Day 0	-0.20	-0.11	0.13	‡		
Pain Day 1	-0.19	0.12	0.17	‡		
Radiculopathy	0.58	0.53	**0.06**	0.04	0.39	0.93
Comorbidity	0.24	0.14	**<0.001**	0.12	0.09	0.23
Dependency score	-0.97	0.21	**<0.001**	-0.14	0.27	0.59

‡ not included in multivariable analysis as they were not significant in univariable analysis, *p*<0.1 for univariable and p<0.05 for multivariable in bold

Table 3. 4: Summary of the patients discharged to home with or without skilled assistance

Variables		No skilled assistance Mean (SD)	Skilled assistance Mean (SD)	*p*
n		229	60	
Age (years)		54.31 (12.12)	57.54 (12.42)	0.07*
Gender	Female (%)	46.3%	53.3%	0.21†
	Male (%)	53.7%	46.7%	
Marital status	Married (%)	74.2%	53.3%	**<0.02†**
	Single/Divorced/ Widowed (%)	25.8%	46.7%	
BMI (kg/m^2)		31.45 (6.17)	30.91 (6.06)	0.54*
Housing	House (%)	90.1%	85%	0.14†
	Other (%)	9.9%	15%	
Living status	Family (%)	80.1%	71.7%	0.09†
	Other (%)	19.9%	28.3%	
Prior level of function (PLOF)	Dependent (%)	1.7%	3.3%	**<0.01†**
	Partially dependent (%)	32.3%	58.3%	
	Independent (%)	66%	38.4%	
Change in hemoglobin level (gm/dl)		-1.70 (1.23)	-1.85 (1.19)	0.38*
Change in hematocrit level (%)		-1.46 (5.87)	-2.96 (5.34)	0.07*
LOS (days)		3.32 (2.57)	6.17 (4.23)	**<0.001‡**
Gait distance (feet)		234.78 (140.43)	181.31 (143.65)	**<0.01‡**
Balance score (Sitting and standing balance)		6.62 (1.72)	5.73 (1.84)	**0.01‡**
	Independent (%)	16.6%	6.6%	**0.01†**
Functional dependency score	Partially dependent (%)	47.6%	35.1%	
	Maximum dependent (%)	35.8%	58.3%	
Intraoperative fluid infusion (mL)		2176.70 (971.78)	2482.05 (1080.54)	**0.04***
Pain 0		4.63 (1.10)	4.58 (1.17)	0.72*
Pain 1		4.56 (1.15)	4.47 (0.95)	0.57*
Radiculopathy	Yes	37.5%	40%	0.87†
	No	62.5%	60%	
Comorbidities		1.14 (1.59)	1.68 (1.94)	**0.03‡**

Table 3. 5: Univariable and multivariable logistic regression analyses for discharge to home with or without skilled assistance

Factor	Univariable analysis			Multivariable analysis		
	β	SE	*p*	β	SE	*p*
Age	0.02	0.02	**0.07**	0.03	0.02	0.84
Marital status‖	0.93	0.81	**<0.001**	0.85	0.412	**0.04**
Gender	-0.28	0.123	0.33	‡		
BMI	-0.02	0.03	0.54	‡		
Housing	0.56	0.59	0.19	‡		
Living status	0.51	0.29	0.13	‡		
PLOF¶	-0.97	0.21	**<0.001**	-0.47	0.22	**0.04**
Change in hemoglobin level	-0.11	0.12	0.38	‡		
Change in hematocrit level	-0.05	0.03	**0.07**	-0.02	0.03	0.58
ln (LOS)	1.74	0.32	**<0.001**	1.46	0.34	**<0.001**
sqrt (Gait)	-0.09	0.03	**<0.001**	0.03	0.04	0.59
Assistive device	0.50	0.19	**0.001**	-0.37	0.28	0.19
Balance Score	-0.30	0.09	**<0.001**	-0.09	0.13	0.48
Total fluid volume	0.01	0.00	**0.04**	0.01	0.01	0.57
Pain Day 0	-0.01	0.14	0.92	‡		
Pain Day 1	-0.05	0.13	0.95	‡		
Radiculopathy	-0.12	0.30	0.69	‡		
Comorbidity	0.17	0.08	**0.03**	-0.06	0.11	0.61
Dependency score	0.74	0.10	**0.01**	0.66	0.35	0.06

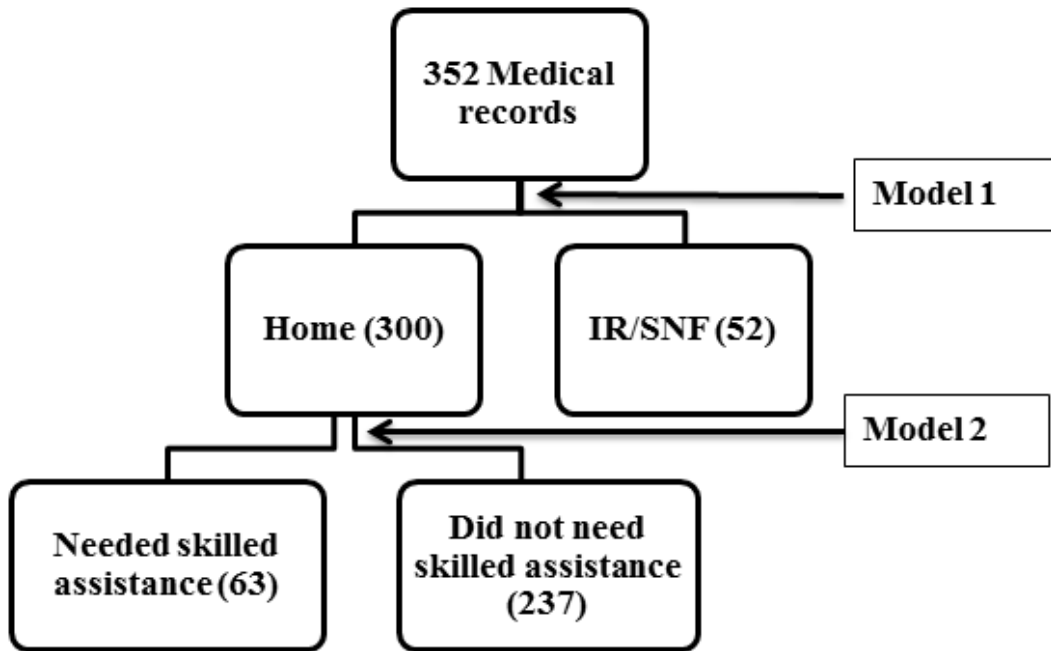‡ Not included in multivariable analysis as they were not significant in univariable analysis, *p*<0.1 for univariable and p<0.05 for multivariable in bold, ‖ (0: married, 1: single (reference category)), ¶ (0: dependent, 1: modified dependent, 2: independent (reference category)).

Figure 3. 1: Allocation of cases to groups and subgroups
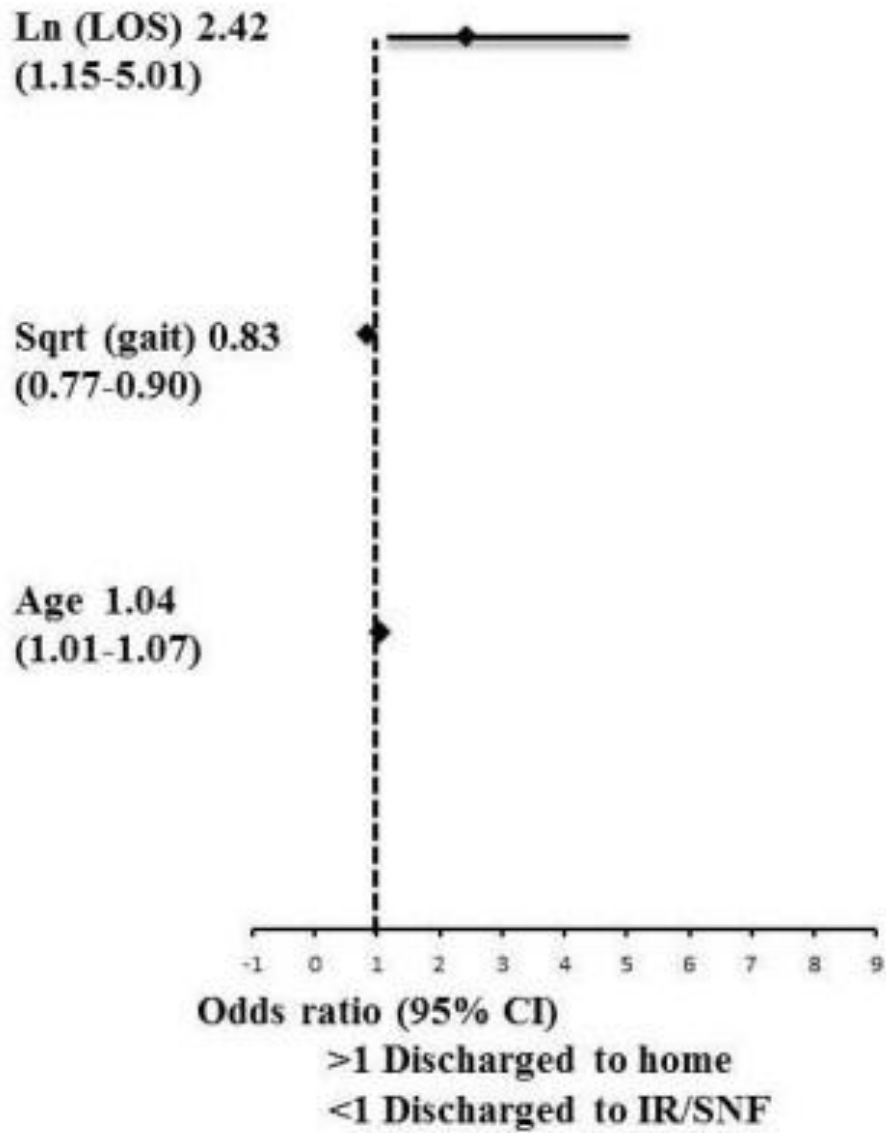
Figure 3. 2: Forest plot of odds ratios and confidence intervals (CI) of significant factors from multivariable analysis, predicting discharge to home vs. IR/SNF

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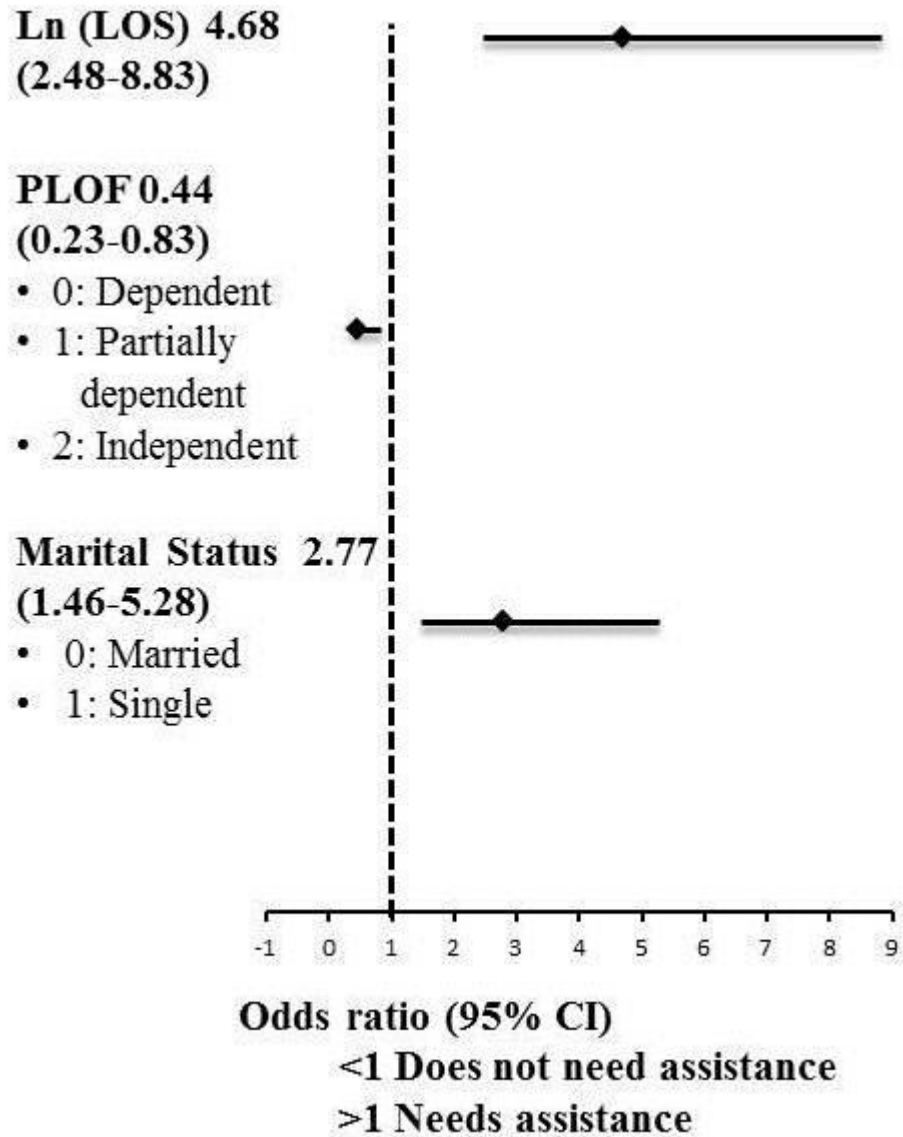
Figure 3. 3: Forest plot of odds ratios and confidence intervals (CI) of significant factors from multivariable analysis, predicting discharged to home with or without skilled assistance

Chapter 4

Investigating and Predicting Early Lumbar Spine Surgery Outcomes

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4.1 Structured Abstract

Study Design: Exploratory, prospective, and observational-cohort study. Patients were assessed one week before posterior Lumbar Spine Surgeries (LSS) of discectomy, laminectomy, or fusion and 2 weeks after hospital discharge.

Objective: To examine the change in patients' clinical status after LSS, and to explore presurgical variables as predictors of surgical outcomes.

Summary of Background Data: Past studies have investigated presurgical predictors for short- and long-term postsurgical outcome measures (6 weeks to10 years). No study till date has investigated the postsurgical outcomes as early as 2 weeks following hospital discharge after LSS.

Methods: Sociodemographic and medical information were extracted from patients' electronic medical records (n=46) scheduled for posterior LSS. Prior to LSS, subjects completed the following questionnaires: back and leg visual pain analogue scale (VAS), Ronald Morris questionnaire (RMQ), Modified Somatic Perception questionnaire (MSPQ), SF-36, The Fear-Avoidance Beliefs Questionnaire, and Beck's Depression Inventory. After 2 weeks of discharge, surgical outcomes were assessed with VAS, RMQ, EuroQol questionnaire, and patient-perception of improvement. Prediction models were constructed to examine pain, function, quality of life, and patient-perception of improvement at 2-weeks postsurgery.

Results: At two weeks post hospital discharge, patients demonstrated significant reduction in back and leg pain, and improvement in function. MSPQ and symptom's duration were significant predictors of back pain, while type of diagnosis and use of analgesics were significant predictors of leg pain. Baseline MSPQ and RMQ were significant predictors of RMQ. MSPQ, gender, and back pain were significant predictors of quality of life. Back pain, leg pain,

depression, smoking, and worker's compensation were significantly associated with patient-perception of surgery outcomes.

Conclusions: Baseline sociodemographic, clinical, work related, and cognitive behavioral could determine early LSS outcomes. The results of this preliminary study could be viewed as directory to identify potential risk factors for unfavorable outcomes at early stages following LSS.

Key words:

Lumbar spine surgery; surgical outcomes; predictors; pain; function; prospective; back pain; leg pain; fusion; laminectomy; decompression; somatic; patient-perception

4.2 Key Points

- The study suggests clinical improvement as early as 2 weeks post hospital discharge following LSS.

- Symptom's duration, type of diagnosis, and preoperative use of analgesics could predict back and pain intensity after surgery.

- Females and patients who had high preoperative back pain could have inferior quality of life.

- Somatic perception predicted back pain, function and quality of life and can be routinely assessed at pre-surgery to guide post-surgery outcomes.

- Preoperative high back and leg pain intensity, high depression symptoms, smoking, and having worker's compensation suggest negative patient-perception of improvement after LSS.

4.3 Mini Abstract

The aim was to identify predictors of lumbar spine surgery 2 weeks post-hospital discharge. Sociodemographic, certain presurgical clinical and cognitive behavioral variables and work status predicted postsurgical back pain, leg pain, function, quality of life and patient-perception of improvement. This knowledge could guide timely interventions.

4.4 Introduction

Low Back Pain (LBP) is one of the most common health problems globally, having significant impact on individuals, community, and health care system.(Dionne, et al., 2006; Rapoport, et al., 2004) Lumbar Spine Surgery (LSS) is usually considered a treatment of LBP when conservative management fails. In spite of LSS being reported as a more efficient treatment than the nonsurgical management,(Weinstein, James N., 2010; Weinstein, J. N., et al., 2008; Weinstein, J. N., et al., 2009) the improvements gained from LSS are not always uniform, possibly due to complexity and various sources of LBP.

Postsurgical pain, function/disability, return to work, and quality of life have been used to determine the results of LSS.(den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Mannion, et al., 2010; Mannion, Denzler, et al., 2007; Mannion & Elfering, 2006; Mannion, Junge, et al., 2009; Trief, et al., 2006; Zheng, et al., 2002) Patient-perceived improvement is also an important measure as it defines success from the patient's perspective on improvement and achievement of goals. (Deyo, et al., 1998; Mannion, Junge, et al., 2009) Because surgical outcomes are multidimensional, a comprehensive assessment of surgical outcomes could lead to more accurate results.

Several studies have suggested that the gain from surgery is related, to some extent, to preoperative factors.(Carragee, et al., 2003; DeBerard, et al., 2009; den Boer, Oostendorp, et al., 2006b; Gaetani, et al., 2004; Kurd et al., 2012; LaCaille, et al., 2005; Mannion, et al., 2010; Mannion, Denzler, et al., 2007; Mannion & Elfering, 2006; Mannion, Junge, et al., 2009; Mannion, Porchet, et al., 2009a; Nygaard, et al., 2000; Trief, et al., 2006) Further, certain selection criteria for LSS may improve surgery results. However, the evidence about use of

preoperative determinants as selection criteria for LSS success is inconclusive, and postsurgery outcomes are often hard to measure as surgical results vary from patient-to-patient.

Past studies have primarily investigated presurgical variables to predict short- and long-term, from 6 weeks to 10 years, postsurgical outcomes. Studies that assessed the predictors of long term surgical outcomes are useful to determine the natural course of surgery and long-term effects of the surgery. However, predicting outcomes early after surgery may be beneficial in determining the direct effects of surgery without possible confounding factors such as deterioration of the degenerative disease or benefit of postsurgical therapies. No study till date has investigated the postsurgical outcomes as early as two weeks following hospital discharge, mainly because the patients are recovering from surgery during this duration. However, the effects of surgery or determinants of surgical outcomes during this recovery period are important to patients needing health care services following surgery and timely implementation of adequate interventions.

Predicting early postsurgical status may assist clinicians and caregivers to set doable expectations for patients and family members. Secondly, identification of such presurgical predictors/determinants will help clinicians to identify risk factors that will not only aid in selecting a suitable candidate for the surgery, but also identify patients at risk following surgery. Finally, this knowledge could assist clinicians to provide individualized instructions and restrictions upon discharge, and clearly communicate expectations of returning back to normal activities and work. Subsequently, a need for early outpatient interventions could be identified and implemented to improve surgical outcomes.

The aims of this exploratory study were to (i) examine the change in patients' clinical status after the LSS and (ii) explore possible presurgical predictors of surgery outcomes as early

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as 2 weeks following LSS of discectomy, laminectomy, or fusion. We hypothesize that patients will demonstrate significant reduction in back pain, leg pain, heightened, medication usage, and increase in function. Secondly, we hypothesized that sociodemographic and presurgical clinical and psychological variables will be significant predictors of pain, physical function, quality of life, and patients' perception of improvement after the surgery. (Carragee, et al., 2003; DeBerard, et al., 2009; den Boer, Oostendorp, et al., 2006b; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Gaetani, et al., 2004; LaCaille, et al., 2005; Mannion, et al., 2010; Mannion, Denzler, et al., 2007; Mannion & Elfering, 2006; Mannion, Junge, et al., 2009; Nygaard, et al., 2000; Trief, et al., 2006)

4.5 Materials and Methods

Study design

This is an exploratory, prospective, and observational-cohort study conducted at the University of Kansas hospital. We received Human Subjects Committee approval to start the study in June 2011. We extracted data from patients' medical records, who were undergoing LSS, and prospectively assessed patients with self-reported questionnaires at one week before the surgery and two weeks following hospital discharge.

Participants

Potential subjects were patients with chronic LBP, who were scheduled for posterior LSS. Subjects, needing spinal surgery, were identified by a neurosurgeon and an orthopedic surgeon) for study participation and were approached in person during their outpatient visit approximately one week before the date of surgery.

Subjects were included in this study if they were 18 years of age or older, were candidates for one of the following three lumbar surgeries: discectomy, laminectomy or fusion, and could understand written and spoken English. They were excluded if they had spinal bone tumor or infection, spine trauma that caused movement limitation, significant head trauma, psychiatric disorders or severe memory problems reported by the patients, or any neurological disease that affected their cognition and/or movement. After meeting the inclusion and exclusion criteria, subjects were consented for the study and informed about accessing their medical files to collect additional data relevant to our study. The informed consent was approved by our Institutional Review Board (HSC # 12595).

Procedure

Medical records were reviewed using data extraction to standardize the procedure. Our research team members who reviewed the medical records were not involved in the clinical assessment or the treatment of the patients. The data collected from the medical records were: age, gender, race, marital status, body mass index (BMI), worker's compensation, physical work load (unemployed or light load, or heavy load), smoking history (smoker, nonsmoker), alcohol use (yes, no), comorbidities, previous LSS, preoperative diagnosis, LBP duration, preoperative analgesics used.

At baseline, subjects completed self-reported questionnaires at home, so they were not fatigue or stressed about being in the clinic, and experienced no influence from health care providers. The subjects were asked to complete the questionnaires and returned in a self-addressed and stamped envelope. The following questionnaires were included:

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Visual Analogue Scale (VAS)(Price, McGrath, Rafii, & Buckingham, 1983): is used to measure pain intensity on 10-cm horizontal line, anchored by the verbal descriptors "no pain" (score 0) and "pain as bad as it could be (score 10). Patients were asked to rate their back and leg pain separately averaging over the last week.

Roland-Morris Questionnaire (RMQ)(Roland & Morris, 1983): is a disability scale with 24-items. Patients select yes or no response for each item. Higher scores reflect higher disability.

Fear-Avoidance Beliefs Questionnaire (FABQ)(Waddell, Newton, Henderson, Somerville, & Main, 1993) is an instrument to measure how fear and avoidance of pain affects patients with LBP. The 16-items scale contains 5-item for physical activity and 11-item for work activity. Patients indicate their response on0 to 6 Likert scale, 0= completely disagrees, 3=unsure, and 6=completely agree. Higher scores reflect higher level of fear avoidance.

Modified Somatic Perception Questionnaire (MSPQ)(Main, 1983) is a13-item scale designed to measure somatic complaints and autonomic perception in patients with LBP.(Donaldson et al., 2011) Patients rate how much they have been bothered by each symptom/ item on a 4-point Likert scale (0=not at all, 3= extremely bothered). Higher scores demonstrate greater somatic (maximum=39) complaints.

Beck's Depression Inventory (BDI)(Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) is a 21-item scale to measure attitudes and symptoms of depression. Patients rate how applicable each item relates to their case, starting with 0 as unrelated to 3 as totally related. Higher scores indicate greater depressive symptoms or attitudes.

Short Form (36) Health Survey (SF-36)(Ware & Sherbourne, 1992) is widely used scale to assess general health and health related quality of life. The scale has two major components: physical component score (PCS) with questions related to physical health and Mental

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Component Score (MCS) with questions related to mental health. Higher scores indicate better quality of life.

Two weeks after hospital discharge, subjects rated their back and leg pain on VAS scale, and completed RMQ. In addition they completed the following questionnaires:

European Quality of Life Scale (EuroQol-5D) (© 1990 EuroQol Group. EQ-5D™):(Fransen & Edmonds, 1999; Janssen, Lubetkin, Sekhobo, & Pickard, 2011) has five generic health status items: Mobility, Self-Care, Pain/Discomfort, Usual activities, and Anxiety/ Depression; each item scored on a 3-point response scale: no problem, moderate problem, or sever problem. (Fransen & Edmonds, 1999; Janssen, et al., 2011) The scores from five items are then converted to 0.0-1.0 index. A higher index value indicates better quality of life.

Patient-perception of improvement: In addition, subjects rated their perceived improvement of back pain, leg pain, function, and general health using a 9-point Likert scale where 1=very much improved and 9=very much worse. The scores were then dichotomized into better or worse (unchanged or feeling worse).

Statistical analysis

IBM SPSS Statistics 20.0 (SPSS Inc. Chicago, IL) was used for statistical analyses. We used mean and standard deviation to describe continuous variables and frequency to describe categorical variables. To examine the changes from presurgery to postsurgery, we used paired t-test for continuous variables and McNemar test for categorical variables.

We initially used univariate regression analysis to identify potential presurgical predictors. Variables meeting significant level, 0.15, were considered as possible predictors for final regression models. We then used a series of multivariate linear regression to construct

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predictor models for back pain, leg pain, RMQ score, and EuroQol-5D index. Controlled stepwise regression was used to control for presurgical pain in the pain models and presurgical RMQ in the functional model. We used multivariable logistic regression (enter method) to predict patient-perception of improvement (improvement or no improvement) in back pain, leg pain, function, and general health.

4.6 Results

Patients' demographic and baseline characteristics are summarized in table 1. Of the 46 patients, 35 reported improvement in back pain and 39 improvements in leg pain (Table 2), while the others reported either no change or worse pain.

In comparison to presurgery levels, there was statistically significant improvement (Table 2) in back pain (mean difference=3.52, p<0.001), leg pain (mean difference =3.87, p<0.001), and function (RM mean difference = 2.71, p=0.031). The change in type of analgesic used by patients was not significant (p=.774). Of the 46 patients, 35 reported improvement in back pain, 39 improvements in leg pain, 35 improvement in function, and 34 improvement in general health, while the others reported either no change or worse pain.

Back pain and leg pain models

Significant predictors of postoperative back pain were MSPQ score (p=.042) and symptoms duration (p=.020) with preoperative back pain intensity controlled (Table 3). These results showed that for a one-unit increase in MSPQ score, back pain is expected to increase by 0.14 points (95%CI=.01 - .27). When the duration of symptoms is increased by one month, back

pain is likely to increase by .04 points (95%CI=.01 - .06). The model predicted 41.5% of the variation in postoperative back pain.

Diagnosis and preoperative use of opioids were the only significant predictors for postoperative leg pain (p=.007 and 042, respectively) in the model with preoperative leg pain intensity controlled (Table 4). Patient with diagnosis of spondylolisthesis is likely to have .62 points (95%CI=-.36 - 1.59) higher leg pain. Patient with preoperative use of opioid is likely to have more leg pain by .78 points (95%CI= - .51 - 2.07). The model explained 25.6% of the variation in postoperative leg pain.

Functional model

Baseline RMQ score was the significant predictor (p=.010) of postoperative RMQ and explained the majority of variation in the model (39.6/47 %), despite controlling for this variable (Table 5). For every one point increase in preoperative RMQ scores, the expected change in postoperative RMQ was .52 (95%CI=.13 - .90) MSPQ was also a significant predictor (p=.040). An increase in one point on MSPQ at pre-surgery time, the RMQ score following surgery is likely to increase by .477 points (95%CI=.02 - .93).

Quality of life model

MSPQ score, being a female gender, and preoperative back pain were significant predictors of the EuroQol-5D index (p<.001, p=.007, p=.044 respectively) (Table 6). When the MSPQ score is increased by one score, the EuroQol-5D index is likely to decrease by 0.011 times (95%CI= -.02 - -.01). Female patients have 0.07-unit (95%CI= -.02 - -.13) higher EuroQol-5D index than males. Finally, when the preoperative back pain is increased by one

score, the EuroQol-5D index is likely to decrease by 0.01 times (95%CI= -.02 - -.00).The back

pain had trivial effect on EuroQol-5D. The model explained 49.8% of the variation in EuroQol-

5D index.

Patients' perception of improvement

High preoperative back pain (odd ratio (95%CI) =5.36 (1.45 – 19.83), p= .012), low

preoperative leg pain (odd ratio (95%CI) = .183 (.04 - .76), p= .019), and high preoperative

depression score (BDI) (odd ratio (95%CI) = .76 (.59 - .97), p= .026) are more likely to have

negative impression of back pain improvement (Table 7). Smokers were more likely to have

negative perception of improvement in function (odd ratio (95%CI) =.19 (.04 – .97), p=.046) and

in general health status (odd ratio (95%CI) =.34 (.06 – 1.82), p=.035) as compared to non-

smokers (Table 8). Patients with higher BMI (odd ratio (95%CI) =1.134 (.99 – 1.30), p=.041)

and who received worker's compensation (odd ratio (95%CI) =.16 (.01-2.00), p=.035) were

more likely to have negative perception of their general health improvement (Table 6). There

was no significant predictor for perception of improvement in leg pain.

4.7 Discussion

To our knowledge, this is the first study to examine clinical symptoms and predict

clinical outcomes at 2 weeks post-hospital discharge following LSS. Subjects reported

significant improvement in back and leg pain and function. Duration of symptoms and somatic

complains predicted back pain whereas type of diagnosis and use of analgesics predicted leg

pain. Somatic complains also predicted function and quality of life and can be used to guide

patients' short-term outcomes. Presurgical functional status determined postsurgical function.

Female gender and less back pain intensity resulted in better quality of life. Patients' perception of improvement was influenced by back and leg pain, depression, smoking, general health status, high BMI and workers' compensation. Majority of patients reported positive perception of improvement in back and leg pain, function and general health.

Previous study have investigated surgical outcomes 6 weeks post discharge following LSS and reported that the changes in pain and function are more obvious in the first 6 weeks in comparison to 6 months.(den Boer, Oostendorp, et al., 2006a) Our results are in agreement with these studies and show that patients experienced significant reduction in back and leg pain, and improvement in function as early as 2 weeks post-hospital discharge. Back and leg pain improvement was also clinically significant.(Hagg, et al., 2003) Analgesics use was not significantly different from pre-surgery to post hospital discharge, suggesting that improvement in back and leg pain was independent of medication use.

Determinant of predictive variables at 2 weeks post hospital discharge can be important to intervene and guide patient care during this recovery phase. Preoperative back pain has been shown to be a predictor of postoperative pain in numerous studies as indicated by a recent systematic review.(Celestin, et al., 2009) Radcliff et al.,(Radcliff et al., 2011) reported higher back pain being associated with symptom's duration > one year, and Ng et al.,(Ng, Tafazal, & Sell, 2007) reported symptoms' duration > two years whereas Sigmundsson et al., (Sigmundsson, Kang, Jonsson, & Stromqvist, 2012) reported no significant difference in symptom's duration. Therefore, symptom's duration could be considered as determinant of postoperative back pain. The average symptoms duration in our sample was approximately 21 months and was significant predictor of back pain even though postoperative back pain might be influenced by incisional pain at 2 weeks post-hospital discharge.

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Preoperative diagnosis was a significant predictor of leg pain intensity. This result contradicts a recent study that concluded the presence of Cauda equina syndrome or degenerative spinal deformity were not significant predictors of presence of numbness after 2 years of LSS.(Hara et al., 2010) However, Sigmundsson et al., (Sigmundsson, et al., 2012) showed that patients who had spondylolisthesis were more likely to have a higher reduction in leg pain, and preoperative use of analgesic predicted higher postsurgical leg pain after one year follow up. Our results also suggest use of analgesics as being possible predictor of leg pain at 2 weeks post discharge.

MSPQ predicted multiple outcomes including back pain, RMQ score, and EuroQol-5D at 2 weeks post-hospital discharge. Previous studies have also reported MSPQ to be significant predictor for short- and long-term outcomes following LSS.(Celestin, et al., 2009; den Boer, Oostendorp, Beems, Munneke, Oerlemans, et al., 2006; Trief, 2000) Since the outcome measures were self-reported, the distressed patients may perceive less gain from the surgery than non-distressed patients.(Block, et al., 2001) MSPQ was a significant predictor for pain and function at one year follow-up and had the highest prediction accuracy in comparison to all other psychological tests.(Graver et al., 1995) MSPQ and depression scores are often used together to identify patients with distress. This combination has shown to be significant predictor of functional disability and pain six and 12 months following LSS,(Okoro & Sell, 2009) and changes in back and leg pain, and functional ability after one year following fusion/decompression surgery.(Trief, 2000) Distressed patients may perceive higher level of pain and develop anxiety or negative behavior (den Boer, Oostendorp, et al., 2006a) and therefore, avoid functional and social activities and rate their function and quality of life lower.

We report high preoperative back pain and female gender as being significant predictors of postsurgical quality of life. Only one study reported that female gender predicted low quality of life after 3 and 12 months of LSS.(Johansson, et al., 2010) Brunstrom and colleagues(Burstrom, Johannesson, & Diderichsen, 2001) found that in general population, women rate quality of life significantly lower than men, specifically the depression/anxiety and pain subscales indices to be lower in women in comparison to men.

We also examined patients' perception of improvement, which depended on pre-surgical back and leg pain, depression scores, smoking, general health status, high BMI and workers. Smokers have negative perception of improvement on health and functional status. Nicotine is well documented to delay early vascularization and consequently delay healing from surgery and bone graft union.(Andersen, et al., 2001; Glassman, et al., 2000) Trief and colleagues (Trief, et al., 2006) reported that smoking predicted general health status and functional status at 12 and 24 months following lumbar spine fusion. Smokers showed to have less improvement in comparison to non-smokers even after 2 years of lumbar decompression/fusion. They had greater use of analgesics, less walking ability, and inferior quality of life. (Sanden, Forsth, & Michaelsson, 2011)

Patients who had high depression symptoms had negative perception of improvement for back pain, while patients who had worker's compensation had negative perception of improvement in function. Depressive symptoms are well related to low back pain, (Carroll, Cassidy, & Cote, 2004; Currie & Wang, 2004) and after surgery patients with depressive symptoms may continue to perceive pain as unchanged or even worse. There are many studies showing work related variables like worker's compensation,(LaCaille, et al., 2005; Trief, 2000) high physical workload,(Block, et al., 2001; den Boer, Oostendorp, et al., 2006b) preoperative

work status, (Anderson, et al., 2006), number of days off from the work , (Nguyen, 2011), and weekly wages were predictors of LSS outcomes.(Nguyen, 2011)

This is an exploratory study and results in our study should be validated with lager studies in future. Other variables may be important and significant in predicting outcomes at 2 weeks follow up with larger sample size. Other clinical outcomes such as assessment of personality and patients' expectation from the surgery, and objective physical examination should also be tested before surgery and included in regression model in future, as these variables have shown some predictive values in other studies.(Aalto, et al., 2006; Block, et al., 2001; Hagg, et al., 2003; Mannion, Junge, et al., 2009; Sigmundsson, et al., 2012) Finally, our study is limited to subjective measures; including objective outcome measures like walking distance could be more accurate measure.

Disclosure: The authors report no conflict of interest

Table 4. 1: Patient baseline characteristics (Mean± SD, or %values)

Variable	Mean ±SD or proportion%
Age	59.20 (12.46)
Gender (Women)	56.5%
Race	
White or Caucasian 96%	96%
Black or African American 4%	4%
Body mass index (kg/m2)	33.38 (7.14)
Marital status	
Married	63%
Divorced/Widowed/separated	22%
Single	15%
Worker's compensation (yes)	9%
Work load	
Unemployed/light load	65.2%
Heavy load	34.8%
Current low back pain duration (months)	21.20 (19.89)
Type of surgery	
Discectomy	15.2%
Laminectomy	39.1%
Fusion	45.7%
Previous back surgery (Yes)	34.8%
Diagnosis	
Disc	31.1%
Stenosis	53.3%
Spondylolisthesis	15.6%
Analgesic	
Non-Opioid	47.8 %
Opioid	52.2%
Smoking (yes)	21.7%
Visual Analogue Scale	
Back pain	6.26 (2.83)
Leg pain	6.02 (2.53)
Pain description	
Dull	47.8%
Sharp	23.9%
Both	28.3%
Ronald Morris Questionnaire	14.68 (5.39)
Fear Avoidance total score	37.74 (18.55)
Modified Somatic Perception Scale	5.89 (4.75)
Beck's Depression Inventory	10.03 (8.34)
SF-36 physical component	26.87 (8.12)
SF-36 mental component	48.92 (12.23)

Table 4. 2: Changes in back and leg pain intensity, function, somatic and type of medications used from presurgery to postsurgery

	Presurgery mean (SEM)	Postsurgery mean (SEM)	Mean difference (95% CI)	p
Back pain	6.26 (.414)	2.74 (.318)	3.52 (2.69 – 4.35)	**<.001**∗
Leg pain	6.02 (.372)	2.15 (.360)	3.87 (2.89 – 4.85)	**<.001**∗
Ronald Morris	14.68 (.813)	11.98 (.977)	2.71 (1.09 – 4.33)	**.002**∗
Analgesics used	Non-Opioid 47.8%	Non-opioid 43.5%		.774‡
	Opioid 52.2%	Opioid 56.5%		

SEM: Standard Error of Mean, *Paired-t-test, ‡McNemar

Table 4. 3: Regression model for back pain at 2 weeks postsurgery

Predictor	B (95% CI)	S.E	Change in R square	p
Constant	1.01(-.90 – 2.93)	.94		.289
Back VAS	.14 (-.09 - .37)	.11	.089	.216
MSPQ	.14 (.01 - .27)	.07	.172	**.042**
Symptoms' duration	.04 (.01 - .06)	.01	.223	**.020**
Total			.484	

VAS: Visual Analogue Scale, MSPQ: Modified Somatic Perception Questionnaire, p<0.05

Table 4. 4: Regression model for leg pain at 2 weeks postsurgery

Predictor	B (95% CI)	S.E	Change in R square	p
Constant	.70 (-1.37 – 2.78)	1.02		.494
Leg VAS	.13 (-.17 - .42)	.15	.001	.359
Diagnosis*	.62 (-.36 – 1.59)	.55	.141	**.007**
Analgesics* use	.78 (-.51 - 2.07)	.73	.12	**.042**
Total			.256	

VAS: Visual Analogue Scale, *reference=Spondylolisthesis, *reference= use of opioid, p<0.05

Table 4. 5: Regression model for function and quality of life at 2 weeks postsurgery

Predictor	B (95% CI)	S.E	Change in R square	p
Constant	2.26 (-2.7 – 7.19)	2.42		.357
RMQ	.52 (.13 - .90)	.19	.396	**.010**
MSPQ	.48 (.02 - .93)	.23	.075	**.040**
Total			.471	

MSPQ: Modified Somatic Perception Questionnaire, RMQ: Ronald Morris Questionnaire, p<0.05

Table 4. 6: Regression model for function and quality of life at 2 weeks postsurgery

Predictor	B (95% CI)	S.E	Change in R square	p
Constant	.85 (.80 - .88)	.02		**<.001**
MSPQ	-.01 (-.02 - -.01)	.01	.341	**<.001**
Gender*	.07 (.02 - .13)	.03	.085	**.007**
Back pain	-.01 (-.02 - .00)	.01	.072	**.044**
Total			.498	

MSPQ: Modified Somatic Perception Questionnaire, *reference = female, p<0.05

Table 4. 7: Regression model for improvement in back pain and leg pain at 2 weeks postsurgery

Back pain improvement					Leg pain improvement				
Predictor	B	Odd ratio (95% CI)	S.E	p	Predictor	B	Odd ratio (95% CI)	S.E	p
Back VAS	1.68	5.36 (1.45 – 19.83)	.67	**.012**	Smoker‡	-1.61	.20 (.05 - 2.77)	1.34	.230
Leg VAS	-1.70	.18 (.05 - .76)	.73	**.019**	Symptom's duration	-.07	.93 (.86 - 1.01)	.04	.091
BDI	.28	.76 (.59 - .97)	.13	**.026**	Back pain	-1.15	.32 (.08 – 1.30)	.72	.111
Constant	3.62	37.34	2.44	.139	Leg pain	.13	1.14 (.75 – 1.74)	.22	.547
					Constant	12.20	3.85	1.97	.080

* Reference = high physical workload, ‡ Reference = smoker, p<0.05

Table 4. 8: Regression model for improvement in function and general health at 2 weeks postsurgery

Function improvement					General health improvement				
Predictor	**B**	**Odd ratio (95% CI)**	**S.E**	**p**	**Predictor**	**B**	**Odd ratio (95% CI)**	**S.E**	**p**
Back pain	-.25	.79 (.55 – 1.13)	.18	.789	BMI	.20	1.22 (1.00 – 1.49)	.101	**.041**
Leg pain	-.09	.93 (.66 – 1.29)	.17	.925	Worker's compensation*	-5.81	.01 (.00 - .87)	2.89	**.045**
Smoker‡	-1.68	.19 (.04 – .97)	.56	**.046**	Smoking‡	-5.71	.01 (.00 – 1.14)	2.98	**.035**
Constant	4.04	56.35	1.58	.347	Somatic perception	.62	1.85 (.89 – 3.85)	.37	.099
					Constant	-5.63	.01	3.35	.093

* Reference = yes, ‡ Reference = yes, p<0.05

Chapter 5

Conclusion

5.1 Summary of findings

LBP and radicular symptoms are major health problems; meanwhile, surgery is increasingly becoming a common choice of treatment. There is a considerable percentage of low back surgery failure leading to failed back surgery syndrome and revision surgeries. Substantial numbers of patients report no change or even worsening in their symptoms following Lumbar Spine Surgery (LSS). Thus, the outcomes of surgery vary from patient to patient but the source of variation is not clearly understood. This necessitates investigating causes that contribute to outcomes of surgery and perhaps revisiting patients' selection criteria for surgery to minimize variability in outcomes. We studied the risk factors that may affect surgery outcomes and determined factors contributing to LSS "success". Our study highlighted the importance of collecting these factors before and during the surgery and hospital stay, and upon hospital discharge.

This body of work established new knowledge and extended the previous literature findings that examined determining factors related to LSS outcomes; in particular- Length of Hospital Stay (LOS), Discharge Placement (DP), clinical outcomes including, pain, function, and quality of life. The ultimate goal of this work is to optimize LSS outcomes and improve the quality of health care service provided to the patients.

5.1.1 Summary of Chapter 2. Structural Equation Model Analysis of the Length of Hospital Stay Following Lumbar Spine Surgery

LOS is an important indicator of appropriate surgery selection criteria, extent of patients' recovery from surgery, efficient care during hospitalization, and availability of continuous community care upon discharge. Thus, understanding variables that predict LOS is important to

guide health care providers for improving patient care, to expedite hospital discharge without compromising patients' recovery, and to minimize health care cost. A small number of studies have investigated the predictors of LOS following LSS, yet present inconclusive and inconsistent results. Moreover, the conclusions of the previous studies are limited by small sample size and a low number of predictors. The purpose of our retrospective study was to use Structural Equation Model (SEM) analysis to better understand/identify predictors of LOS while utilizing large sample size, and numerous potential predictors to study their unique and shared contribution toward LOS. Our results showed that predictors of LOS could be grouped into three latent factors: presurgical, surgical, and postsurgical. The three factors shared 23% of the total 47% variation in LOS, revealing high correlation between the factors. Only Physical Therapy (PT) functional assessment measures showed to have a significant direct effect on postsurgical factors. Postsurgical factors individually explained 19% of the variation in LOS. This study provided a more comprehensive understanding of the variables affecting the LOS following LSS and emphasized the importance of the patient's functional status as a determinant of LOS.

5.1.2 Summary of Chapter 3. Predicting Discharge Placement and Health Care Needs after Lumbar Spine Laminectomy

The next logical step in improving LSS outcomes is to understand variables predicting DP following the LOS. Knowing DP determinants could guide clinicians to establish realistic goals and expectations for patients along with their family members and communicate with other healthcare providers to arrange for timely and efficient transfer from hospital to community care. Many studies have investigated predictors of DP following various orthopedic and neurological conditions; however, to our knowledge, variables predicting DP following LSS have not yet been

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investigated. The purpose of this work was to retrospectively investigate variables predicting DP following LSS, including patient characteristics that lead to home discharge with and without further skilled assistance, or to Inpatient rehab/Skilled nursing facility. The results of this retrospective study indicated that younger age, distance walked during hospital stay, and LOS were the only significant predictors of being discharged to either home or to Inpatient Rehabilitation (IR)/Skilled Nursing Facility (SNF). Whereas, patients who lived alone, had poor prior level of function (PLOF), and stayed longer in hospital were significantly more likely to need skilled assistance after being discharged to home. Future prospective studies are needed to confirm these findings.

5.1.3 Summary of Chapter 4. Investigating and Predicting Early Lumbar Spine Surgery Outcomes

Knowledge of surgical success may lead to better identification of surgery selection criteria and risk factors that need close supervision and timely intervention and doable expectations of patients and family members. There is extensive literature on the predictors of LSS outcomes at short- (6 weeks to 10months) and long-term follow up (12 months to 10 years); however, no study has investigated the predictors of surgery outcomes as early as two weeks post discharge after LSS. Investigating surgical outcomes and predictors of surgery success at such short period post-discharge will aid in identifying patients at high-risk and directing timely interventions to potentially optimize long-term effects of surgical outcomes. The purpose of our study was to examine the change in patients' clinical status after LSS, and to explore presurgical predictors of surgical outcomes at 2 weeks of discharge following LSS. Our exploratory prospective study showed a significant improvement in back pain, leg pain, and function as early

as 2 weeks post hospital discharge following LSS. Somatic perception and symptom duration were found to be significant predictors of back pain, while type of diagnosis and preoperative use of analgesics were significant predictors of leg pain. In addition, preoperative functional and somatic perception levels were found to be significant predictors of functional status. Female gender and patients with high preoperative back pain demonstrated a significantly diminished quality of life. Preoperative high back and leg pain, high depression symptoms, smoking, and access to worker's compensation associated with negative patient-perception of improvement after LSS. Further studies with a larger sample size are needed to confirm the results.

5.2 Clinical implications

5.2.1 Chapter 2

LOS is an important health care indicator; therefore, it is essential to identify and evaluate factors that influence LOS. It will not only permit early goal setting and intervention but also prepare patients and their family for earlier discharge. LOS predictors assist in identification of potential limitations in patient treatment and facilitate communication of established plan of care from hospital setting to the community care. Also, it will be important to have realistic LOS for health care payers.

Older age should be considered for surgery selection criteria as it is associated with the need for extended LOS, more health care and social support after the surgery. Older patients often present with comorbidities and are more vulnerable to complications, leading to slow recovery and longer LOS.

The PLOF and level of assistance needed for daily activities were also found to be important pre-surgical predictors. Thus, patients' functional status should be routinely

determined with standardized tests of either subjective tests like Oswestry Disability Index or

Ronald Morris Questionnaire (RMQ), or objective tests like walking capacity, 6-minute walking

test, and/or Timed Up and Go test. Also, presurgical assessment by physical therapists and

occupational therapists would provide an accurate assessment of function and dependency level

that can be considered for surgery selection criteria and used to establish postoperative

rehabilitation goals and interventions.

Physiological measures such as hemoglobin level seemed to be a useful predictor of LOS

and consequently LSS outcomes. Fortunately this variable could be controlled. Clinicians should

consider strategies to reduce blood loss and maintain the hemoglobin level within physiological

limits through pharmacological interventions and perioperative blood transfusion.(Diamond,

Conaway, Mody, & Bhirangi, 2006) Elevating hemoglobin level before the surgery may help

improve surgery outcomes and ultimately reduce LOS.

Illness severity, occurrence of complications, and the need for ICU admission all

predicted LOS. Type of surgery was associated with these factors and should also be considered

to predict LOS. For instance, fusion is usually accompanied with more complications and

accounts for possible ICU admissions. Usually surgery is considered when all the conservative

management fail, however longer duration of back pain symptoms and the progression of the

disease may affect the severity of the disease and consequently lead to poor surgery outcomes. It

is important to identify early the patients who may not benefit from conservative management

and may eventually need surgery; therefore, limiting the progression in the severity of the

disease with time.

Interestingly, the postsurgical factors where the strongest predictors of the LOS in

comparison to presurgical and surgical factors. Moreover, post-surgery PT functional assessment

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variables were the only variables that had significant effects on the postsurgical factors in the SEM. This highlights the importance of involving physical therapists in discharge planning and discharge decision making. Physical therapists could use standardized and more sensitive functional assessments and thus better assess and predict LOS in patients.

In clinical practice, recovery from anesthesia, controlling pain, wound healing, absence of complications, or removal of drain are among the most common criteria for patients discharge. Our results showed the importance of functional performance, as predictors for LOS at either presurgery or postsurgery time frames. Based on these results, we recommend that patients should be enrolled in the rehabilitation program before the surgery and focus on improving functional status during hospital stay in order to reduce the LOS and improve surgery outcomes.

5.2.2 Chapter 3

Identifying variables that could predict discharge placement could assist clinicians in discharge planning and communicate realistic expectations and the level of care needed following hospital discharge to the patients and their family members. From the several variables investigated as possible predictors of DP, age, distance walked during the hospital stay, and LOS were found to be significant predictors of DP. Elderly patients are more vulnerable to negative outcomes after surgery, which might impact their return to previous functional ability. As previously discussed, elderly patients often present more comorbidities and complications. Therefore, careful assessment of elderly patients' clinical status before the surgery and of the availability of resources for post discharge continuous care should be considered.

Longer distance walked reflects better functional status, better balance, higher independent status, greater motor control, and better endurance. After surgery, patients are

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encouraged to mobilize as early as possible, often on the first post-operative day. Gait could be viewed as a modifiable factor that could be manipulated to optimize patient recovery after surgery. Clinicians should encourage their patients to be active before the surgery as this might improve their chances of recovery following surgery. Also, it would be useful to encourage patients to walk several times a day during their inpatient stay.

Extended LOS is associated with discharge to intermediate care and need for skilled care assistance when being discharged to home. It is not clear if this result is explained by occurring in patients who are medically instable and have low functional level and thus will need longer days at hospital and more health care services after discharge, or by the extended LOS might have decreased patient functional level due to bed rest and lack of functional activities.

Patients who live alone and those with low PLOF are more likely to need skilled assistance at home. These results highlight the importance of social support system, and family involvement. Family members may also consider being actively involved in discharge planning and understanding surgical restrictions to assist patients.

Identifying these predictors of LOS will facilitate early communication with family members to timely prepare for possible short LOS and patients' need for support. Involving family in patient's care would not only be a cost effective option for all parties involved but can also help free some hospital resources for more serious cases.

Similar to findings of the LOS, the presurgery functional level seems to be important factor and highlights the significance of PT assessment in determining health care services following LSS, although the DP and level of assistance needed at home after discharge are decisions of the multidisciplinary team. These functional predictors for DP, and for LOS, could be used to guide fast-track rehabilitation program after LSS. The fact track programs have

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already been shown to be efficient in reducing LOS and improving surgery outcomes following similar orthopedic surgeries.(den Hertog, Gliesche, Timm, Muhlbauer, & Zebrowski, 2012; Kehlet, 2013)

5.2.3 Chapter 4.

The aim of this study was to increase knowledge about predictors of LSS, specifically the predictors of the short-term outcomes. We investigated the results of LSS as early as 2 weeks post discharge and it was found that even in this short follow-up period, patients reported significant improvement in pain and function. Additionally, several socioeconomic, clinical, and cognitive behavioral variables as predictors of short-term surgery outcomes were identified.

Recently with current advancement in surgery techniques, the recovery from surgery is becoming faster. This indicates studying the short term results of the surgery is needed. Also, identifying predictors for short term outcomes would be helpful information for patients' surgery decision making and surgeon's selection criteria. Identifying risk factors that predict negative outcomes especially the modifiable ones could guide early interventions to optimize surgery results. Our results showed that patients could demonstrate early improvement after the LSS, and such findings suggest early rehabilitation programs would be feasible to start early after the surgery. Earlier rehabilitation program, when appropriate, showed to improve the surgery outcomes after surgery more than late programs.(Oestergaard et al., 2012) One of the advantages of undergoing surgery is early resumption of activities and ability to return to work. Gradual return to work could be started as early as 1.2 weeks of lumbar discectomy and 8 weeks to fully return to duty.(Carragee et al., 1999) Therefore, identifying the surgery outcomes in this

short period, could facilitate prediction and early planning to return to work and to presurgical social and functional life.

RMQ and MSPQ, and BDI scores were significant predictors of several outcomes including pain, function and quality of life. However, these questionnaires are not usually included in routine clinical examination. Therefore, including such tests would improve surgery selection criteria and could be informative of the level of improvement expected after surgery.

Surgery seems to be useful in decreasing pain and improving function, however sometimes surgery fails to resolve these symptoms because of the consequences of the chronicity of the LBP. This is evident by our results showing that cognitive behavioral and work related variables could predict negative outcomes for the surgery. Presurgery consultation and work modification could be included to optimize the surgery results, since work related factors and cognitive behavioral factors were significant predictors of surgery outcomes.

The results of the study would be helpful to communicate information to patients to help in decision making regarding the surgery. The timeline of surgery from hospital admission to discharge could be discussed with patients. Positive outcome predictors could be conveyed as the negative predictors and strategies to improve these predictors can be discussed and implemented.

5.3 Reflection, limitations, and future directions

5.3.1 Reflection on the projects

In chapter 3, we studied the predictor of DP following LSS. In this project we collaborated with the medical informatics division at the University of Kansas Medical Center, which has developed the Healthcare Enterprise Repository for Ontological Narration (HERON),(Waitman, et al., 2011) that provide researchers with access to de-identified electronic

medical records from the University of Kansas hospital and clinics. At that time, the HERON project was under development and we were among the first researchers to use this electronic system and beta-test the procedure of extracting and managing data resources. Therefore, the process of identifying our cohort of interest and obtaining the required data of interest was challenging and required further modifications of data extraction steps. Creating data query and the data mining were tedious and time consuming. Furthermore, many essential variables, for our study, were not available such as race, severity of illness, diagnosis, comorbidities, and LOS. We could collect some of these variables manually, for example LOS was calculated by subtracting the last day inpatient hospital service was provided and the date of surgery. In addition, the whole dataset was not complete resulting with multiple missing data and limited sample size. Based on our feedbacks, the informative department was able to make several modifications to improve their data set and extraction process.

In chapter 2, we studied the predictors of LOS following LSS. We extended our collaboration with the medical informatics department to obtain access to medical records providing data extracted for chapter 2. Upon the time of this project, the HERON system was updated, and we were able to access more variables resulting in less missing data. In this project, we had a better experience in the Heron system, and we were able to extract more outcomes to include in our prediction models. Also, we were able to use formal data for some variables, i.e. LOS was obtained from hospital billing department rather than from manual calculation of LOS; although, via manual method, we were able to identify 1,500 subjects out of which approximately 50% did not have official hospital stay data recorded in the billing department. Therefore we were able to use only 600 subject for the LOP study. It is hoped that HERON

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system will continue to improve and our feedbacks will result in less missing data and a full data set for future studies.

Despite this limitation, we were able to obtain a high sample size and numerous variables, which allowed us to use SEM, a method rarely used to analyze predictors of surgical outcomes such as LOS. We used SEM in order to explore the multifaceted nature of the determinants of LOS. In prediction models, different studies may yield different results. This occurred as a result of different variables entered into the model and relationship among the variables. As an example, including PLOF and dependency score separately in the model may result in both variables being significant, however when entered in the model, one variable would wash out the effect of the other maintaining only one as significant. Including two highly associated factors could breach the collinearity assumption of the model, and/or affect the fitness of prediction model. Note that PLOF and dependent score are relatively calculated in different time points; PLOF was calculated before the surgery and dependency score was collected after the surgery in our model. Therefore, we chose to construct SEM using presurgical, surgical, and postsurgical variables. As we included numerous variables we aimed at better understanding how these factors interact with each other and how they affect LOS. Secondly, this method allowed us to compare the importance of data collected at each time point and study how these stages affected the LOS along with their unique and common variability.

The work of chapter 4 was based on our prospective observational study. We initially started our project in collaboration with the neurosurgery clinic at Marc A Asher MD Comprehensive Spine Center at the University of Kansas hospital. We expanded our collaboration to the orthopedic surgery clinic shortly after to recruit more subjects and improve the generalizability of the results. One of the limitations of our prospective study is the lack of

control over external factors. The study was observational in design for a real life clinical situation. We did not change any type of services provided to the patient, as we are studying the outcomes of the surgery from real life situations. In a high quality study design, many factors should be controlled, however; our study will be more representative to real life situations. However, we added additional standardized tests at pre-surgery and during hospital stay to take some measures of standardization and followed patients after hospital discharge. Even though the study design presents weakness, it possesses better external validity and is more applicable to clinical practice.

5.3.2 Limitations

Retrospective

We collected the data for chapter 2 and 3 retrospectively. Retrospective studies are not as favorable as prospective studies in research because of many factors outlined below:

1) Missing data for individual or multiple variables: As an example for DP study, the missing data in the age variable was around 10%. For LOS around 1500 possible patients record for analysis were identified, but the dependent variable LOS was only available for around 600 records. For the final records, we had multiple random missing data. Additionally, important variable such as operation time, number of spine level operated, work status, level of education and medication use, should have been included but were not available for our dataset.

2) Inability to collect baseline information: Routine medical examination may not include all necessary tests related to our analysis. For example, cognitive behavioral variables and quality of life have been showed to be important predictors of LSS outcomes.(Block, et al., 2001; den Boer, Oostendorp, et al., 2006a; Graver, et al., 1995; Hagg, et al., 2003; Hara, et al., 2010; Johansson,

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et al., 2010) However, these standardized tests were not conducted at baseline and not available for our prediction models, which could have explained a higher percentage in variation in DP and LOS.

3) Non-standardized data collection method and variables assessed by many clinicians, affecting validity and inter-reliability of the data: While an error in documentation could occur, leading to inaccurate results, we examined the data for accuracy and performed statistical assumptions to account for some of these issues.

Given all these limitations accompanied with the retrospective nature of our study design, the retrospective study remained useful in many ways. A higher sample size and consequently a high power could be achieved. The number of variables to include in the model could be expanded which improved the accuracy of our prediction models. In addition, these types of studies are cost and time effective. Moreover, it could provide the healthcare centers with quality assessment and strategies to improve their service.

External validity of the results

We relatively used a high sample size: 593 for chapter 2 and 352 for chapter 3. With such a high sample size, a high generalizability of results may be anticipated. However, caution should be taken before generalization for the reasons below.

Our cohort and inclusion and exclusion criteria limited the generalizability of results. For chapter 2, the cohort of our study included patients who had only laminectomy and or fusion. We did not include patients who had lumbar discectomy as this type of surgery is becoming more ambulatory and hospital stay is usually not required. We also excluded medical records for

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patients who did not receive PT visits because those records contained many missing variables that are normally documented by physical therapists.

For chapter 3, the cohort of our study included patients who only had laminectomy, because the data extracted from the HERON resulted in 97% of records for laminectomy, and only 3% for fusion, therefore analysis of medical records was limited to those for laminectomy. Thus, the results are only generalizable to patients with laminectomy. In chapter 4, we included patients who had discectomy, laminectomy, and fusion. The sample size was small; therefore, our sample is not an ideal representation of the population. Similar limitations due to the inclusion and exclusion criteria for chapter 2 and 3 are applicable for this study.

It is unknown whether the surgeons had patient selection criteria for their patients, as such some cases might have been withdrawn from surgery with reasons we are unaware of. This might hinder the generalizability of our results. The sample was taken from one facility. There is well documented variation in discharge planning between surgeons, between health centers in one region, and across different regions.(Weinstein, J. N., et al., 2006) However, the retrospective data were taken from different surgeons, and our prospective data were taken from a mix sample from orthopedic surgery and neurosurgery practice.

Sample size

Since the sample size in the exploratory study (chapter 4) is relatively small, the predictability of the aforementioned factors should not be taken as final. Also, some other variables could have shown significant results if the sample size was bigger. The results of this study could be used as directory for future studies. More assessment could be utilized at baseline including assessment of personality, patients' expectation from the surgery at baseline, since

these variables have showed to be predictors of surgery outcomes in other studies.(Aalto, et al., 2006; Block, et al., 2001; Hagg, et al., 2003; Mannion, Junge, et al., 2009) Including higher sample size would provide sufficient power to include more relevant variables as predictors.

Other limitations

It should be noted that these results are with the assumption that surgical skills are optimum and no mistakes were to happen (technical success). However, surgical procedures are not infallible. Most of the prediction studies does not consider failure of the surgery and has an assumption that outcomes are attributable to patient variables only.

Results of the prediction models need to be validated. Future studies could randomly select portion of the data to develop the model and the other portion could be used to validate the developed prediction model.

One of the limitations in the study of LSS predictors is that assessment is mostly through a self-reported questionnaire. Patients with psychological symptoms like distress, depression, or anxiety may perceive the gain from surgery to be lower. Patients filled these reports on their own, however, detailed directions were given and questionnaires are reported to be easy to complete without guidance.

We have selected to study the predictors prospectively. Studying these predictors prospectively allowed introducing some standardized questionnaires and follow up with patients which is not possible with retrospective studies.

5.4 Future directions

5.4.1 Chapter 2 and 3

Few hospitals have adopted clear hospital discharge and DP policy. Our results of LOS, and DP prediction, and other similar studies could guide establishing such policies and direct discharge planning to be based on evidence.

The results of the SEM could be converted to more clinically useful results that enable clinician to calculate expected LOS for patients. An algorithm can be formulated using the significant predictors to calculate the expected LOS. A working sheet or using mathematical software can be used to create such an algorithm, where clinician can insert the values of the significant predictors to calculate the expected LOS. Similar algorithm can also be formulated to calculate who may be discharged to SNF/IR rather than home, and who will need skilled assistance after being discharged to home.

Gait distance could be viewed as reflecting many dimensions of physical function as balance, muscle strength, and endurance. Future studies may investigate if an increase in gait training and distance walked by patients may improve their outcomes. PLOF and gait distance are modifiable factors for both LOS and DP. Therefore, future studies could evaluate if improvement in PLOF and postsurgical walking distance could shorten LOS, change DP or improve other surgical outcomes.

In clinical practice, stability of some physical measures like recovery from anesthesia, controlling pain, wound healing, absence of complications, or removal of drain are among the most common criteria for patients discharge. Our results showed the importance of presurgical and postsurgical functional measures as predictors of LOS and DP. From these results, rehabilitation program could be started before the surgery and increased inpatient rehabilitation may be considered to reduce LOS and improve the surgery outcomes. Methods for assessing function during inpatient stay should be revised and more sensitive assessment tools should be

adopted. More sensitive tools will allow more accurate predictions of LOS, DP, and possibly short and long term surgical outcomes.

HERON system has been updated and it is possible to obtain better data quantity and quality for future researchers. Many variables could be used as predictors for DP, which we were unable to use, including intensive care unit length of stay, race, and ethnicity, use of assistive device, previous surgeries, diagnosis, and severity of illness, complications number, admission day of the week, and number of comorbidities.

In future, prospective studies for LOS and DP need to be conducted to have more definite results. Studying these outcomes prospectively will overcome the limitations faced in retrospective studies and will allow more standardized tests to be used. Additionally, clinical examination data may be gathered including psychological measures (i.e. fear avoidance, depression, and anxiety). A prospective study could allow for follow up with patients and compare the outcomes resulted from short LOS and from being discharged to each of the discharge destination. Qualitative studies including a patient interview component could be informative in better understand the patient's perception of his/her inpatient stay, DP, and presurgical patient expectation. Such information may assist in identifying subjects at high risk, address their needs, and eventually affect surgery outcomes.

The results of these studies could guide future studies aiming to establish patients' selection criteria for surgery. Important preoperative predictors such as function, pain, age, and level of distress could be used to classify patients to three groups: "patients most likely to improve", "patients less likely to improve", and "patients may not benefit from the surgery". Short and long term surgical outcomes could be assessed to validate classification-based predictions for surgical outcomes.

5.4.2 Chapter 4

In our prospective analysis we included subjects who had discectomy, laminectomy, and fusion. Future studies could study each type of surgery separately, as the surgery outcomes from each type would be different.

More preoperative variables could be included as predictors based on results from similar studies. Future studies might benefit from using these factors: pain coping, patients' expectation from surgery, and Distress and Risk Assessment questionnaire. In addition, objective testing like walking capacity, "timed up and go", and other objective testing could be useful to include as predictors. Imaging findings have been shown to be significant predictors and could be also considered also in the future.

The Core Outcome Measure Index (COMI) was tested by separate research groups and showed to be valid, reliable and responsive index in LBP and LSS. (Ferrer, 2006; Mannion, Denzler, et al., 2007; Mannion & Elfering, 2006; Mannion, Porchet, et al., 2009a) The COMI consists of a series of questions where in each question the patient rate their perception, on a 5-point Likert scale, of their back and leg pain intensity, function, symptoms-specific well-being, quality of life, and social and work disability.(Mannion, Porchet, et al., 2009a) This would allow for a more comprehensive analysis in future studies.

5.5 Conclusion

In this dissertation work, we aimed to advance the knowledge about determinants of the LSS leading to improved surgical outcomes. This work could be viewed as adjunct to all studies that predicted short- and long term-outcomes. We expanded on the work of the predictors of

LOS, and we identified more precisely and comprehensively key factors that determine LOS and their unique contribution to LOS. We could establish preliminary guidelines for key factors to consider in discharge planning and identify key factors for clinicians to consider when deciding DP placement and the level of assistance needed upon discharge. Furthermore, we explored the determinant of early post discharge surgery outcomes and provided preliminary guideline to identify risk factors of negative surgery outcomes. These guidelines could assist clinicians in patient selection for surgery and identifying modifiable factors to optimize surgical outcomes. This project highlighted the importance of rarely utilized surgical and immediate postsurgical factor to predict postsurgical LOS and DP. Postsurgical functional and independency assessment were among the best predictors of LOS and DP. Presurgical cognitive behavioral outcomes appeared to be key predictors of short term surgical outcomes.

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