

**The Role of Preoperative Therapies in Recovery from Anterior
Cervical Discectomy and Fusion Surgery for Cervical
Radiculopathy**

by

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ABSTRACT

Background: Cervical Radiculopathy is caused by compression of cervical nerve roots leading to pain and disability of the neck and arms. The role of preoperative therapies on outcomes following anterior cervical discectomy and fusion surgery is unknown. **Aim:** To identify associations between common preoperative therapies and postoperative pain and disability. The preoperative therapies investigated are anti-convulsant and opioid pain medication, spinal injections, physiotherapy and chiropractic treatment, and regular exercise. **Study Design:** Longitudinal analysis of prospectively collected data from 352 patients. **Study outcomes:** Neck pain, arm pain, and neck pain-related disability measured preoperatively and 3, 12, and 24 months post-surgery. **Data Analysis:** Associations between preoperative therapies and outcome were investigated using robust Poisson regression models. **Results:** Univariable: Daily opioid use associated with poor neck disability outcome and spinal injections, physiotherapy, and regular exercise predicted good outcome. Multivariable: Spinal injections, physiotherapy, and regular exercise had causal effect on good neck disability outcome.

DEDICATION

I dedicate this to my family. Thank you to my mother Shelley for the unconditional support. My nan Heather for the consistent faith she has in me. My sister Kelci for keeping me grounded and having my back. My father Bobby, you'll always be missed and I hope you're resting easy. My father figures Greg for sharing wisdom and the hard truths about this world, and Derek for the lifelong skills you taught me. There are many more individuals not named that aided me in my trajectory to this point.

Thank you to the friends who kept the good times rolling.

Finally, this one goes out to the boulevard. Thank you to the hood for making me tough and appreciate what I have.

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List of Symbols, Nomenclature or Abbreviations

ACDF: Anterior Cervical Discectomy and Fusion

CSR: Cervical Spondylotic Radiculopathy

NDI: Neck Disability Index

NPRS: Numeric Pain Rating Scale

MCIC: Minimal clinically important change

MDC: Minimal detectable change

VAS: Visual analogue scale

CSORN: Canadian Spine Outcomes and Surgical Network

Chapter 1: Introduction

Neck disorders are a leading cause of disability in Canada and worldwide (Vos et al., 2016). Moreover, neck pain is becoming more prevalent with a 21% increase in global point prevalence from 2005 to 2015, affecting over a third of a billion people (Vos et al., 2016). Cervical spondylotic radiculopathy (CSR) is a common neck disorder caused by compression and inflammation of the cervical nerve roots (Kang et al., 2020). CSR can result in pain and disability in the neck and arms, including a loss of sensory and motor function in the upper extremities (Finnerup et al., 2016). CSR has a point prevalence from 1.2 to 5.8 per 1,000 people (Mansfield et al., 2020). The surgical gold standard for CSR is currently anterior cervical discectomy and fusion (ACDF) surgery. Previous studies show that predictors like male sex, non-smoking status, and normal distress levels predict good outcomes following ACDF surgery (Hermansen et al., 2013; Peolsson et al., 2003, 2006; Peolsson & Peolsson, 2008). Additionally, early evidence shows that weak narcotic use is associated with worse outcomes following ACDF (Anderson et al., 2009). However, the role of other common pre-operative treatments remains unknown.

Clinical outcomes following ACDF surgery for CSR can vary from patient to patient. Identifying potential predictors of poor outcomes following surgery for CSR can help inform optimal patient selection for clinicians. The aim of this research is to first identify the association between common preoperative therapies and pain and disability following ACDF surgery. The second aim is to investigate the causal effect of predictors by controlling for potential confounding variables. The pre-operative factors to be

investigated are anti-convulsant and opioid medications, spinal injections, pre-operative physiotherapy and chiropractic treatment, and regular exercise.

The prevalence of neck pain and disability will likely increase with the aging population (United Nations et al., 2017). To combat a foreseeable increase in neck pain and disability, it is vital to explore the prognosis and influences of neck conditions. The knowledge gained by our study will assist surgeons with therapy selection and help to set appropriate outcome expectations for patients. This information can help identify those patients most likely to benefit from ACDF surgery. In the long term, this line of research may help to inform health policy and resource allocation through improved clinical outcomes and reduction of unnecessary surgery.

Literature Review

Degenerative Cervical Spine Disease: Cervical Spondylotic Radiculopathy (CSR)

Underlying medical condition

Cervical Spondylotic radiculopathy (CSR) is a condition that refers to compression and inflammation of cervical nerve roots (Abbed & Coumans, 2007). CSR can present symptomatically as pain in the neck, arms, or lower extremities. Compression of the cervical nerve roots can also result in the loss of motor or sensory function, typically in the corresponding dermatome or myotome territory (Finnerup et al., 2016).

Spondylosis describes degeneration of spine and intervertebral disks (Theodore, 2020). Age-related spinal degeneration occurs in most people over their lifetime (Kuo & Tadi, 2020). Spinal intervertebral disc degeneration is present in 71-77% of individuals aged <50 years and above 90% in individuals aged >50 years (Teraguchi et al., 2014). Approximately 85% of people over the age of 60 showed some degenerative changes in their cervical spine (Kuo & Tadi, 2020). Degeneration occurs in two main elements of the spine: degeneration of intervertebral discs and degeneration of facet joints (Theodore, 2020). Some changes with age include bone formation and calcification of the cartilaginous end-plate of the vertebral body (Oda et al., 1988). The cartilaginous end-plate provides a nutritional route to the inner portion of the intervertebral disk, the nucleus pulposus. Following calcification of this structure, degeneration of the nucleus pulposus can occur (Oda et al., 1988). Characteristics of cervical spondylosis include the formation of bony

‘spurs’ or osteophytes, compression of spinal nerves or nerve roots, and narrowing of the intervertebral disk space (Abbed & Coumans, 2007) (Hirai et al., 2021). Osteophytes are small bony projections that form and develop near joint margins. These osteophytes are commonly asymptomatic and cause minor problems. In some instances, however, the osteophytes can form near spinal nerves and protrude on or impinge the surrounding spinal cord or nerve roots. Following the compression of either the spinal cord or nerve roots, pain can occur in the neck or distal tracts of the specific nerve. As the joints and disks in the cervical vertebrae degenerate over time, the spaces, or foramina in the surrounding structures can become narrow (Shedid & Benzel, 2007). Moreover, degeneration of intervertebral disks may cause sections of the disks to bulge into the spinal canal or the intervertebral foramen. Narrowing of the surrounding foramina or bulging of intervertebral disks can result in spinal cord or nerve root compression (Abbed & Coumans, 2007).

Another potential source of pain associated with radiculopathy is inflammation. Inflammation may explain pain in the absence of disk herniation. In degenerating intervertebral disks, disk cells and immune cells express pro-inflammatory cytokines such as interleukin-1 and tumor necrosis factor- α (Wuertz & Haglund, 2013). As the cytokine expression increases, more immune cells are recruited. Immune cells, such as macrophages, are present in degenerating intervertebral disks (Peng et al., 2006). Macrophages can secrete degrading proteolytic enzymes that play a role in the inflammation pathway leading to pain associated with radiculopathy. Proteolytic enzymes breakdown important extracellular matrix components of the nucleus pulposus such as aggrecan and collagen. Moreover, pro-inflammatory cytokines upregulate protease production (Wuertz & Haglund, 2013). These cytokines cause a cascade of inflammatory

responses near the vertebrae and intervertebral disk which may be the non-mechanical source of pain for patients.

When an intervertebral disk ruptures, nuclear fluid is exposed to the surround areas and can contact the local nerve roots. The glycoprotein component of the nuclear fluid is highly irritant to nerves (Marshall et al., 1977). It's suggested that an auto-immune response can be activated upon disk herniation. The nucleus pulposus is contained in the annulus fibrosus after embryogenic development and has no systemic circulation access (Hirsch & Schajowicz, 1952). Moreover, the glycoprotein enters an antigen role which can elicit an auto-immune response and consequently, inflammation.

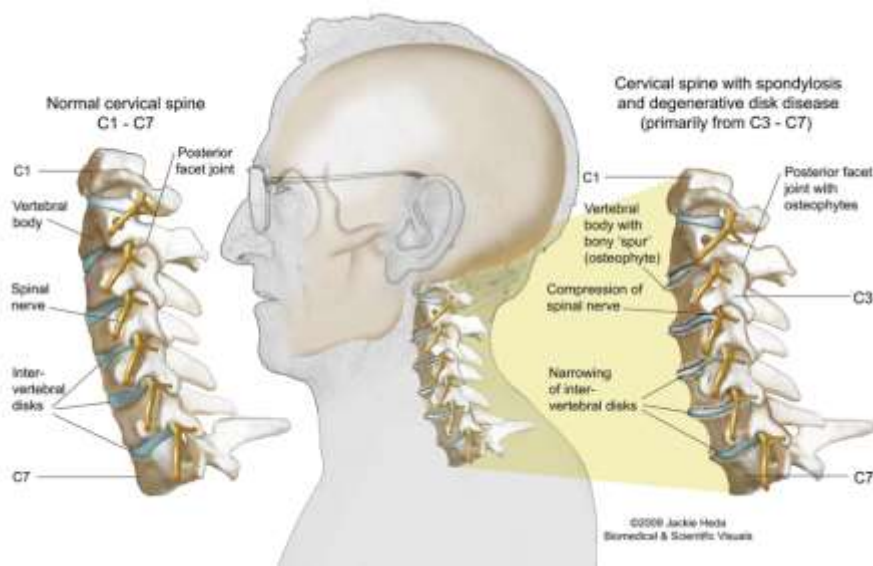


Figure 1: Comparison between a normal cervical spine and cervical spine with spondylosis and degenerative disk disease. Additionally, compression of nerve roots are displayed by osteophytes and narrowing of the intervertebral disk space (**“Osteophytes Archives,” n.d.**) medical illustrator, Jackie Heda © 2009.

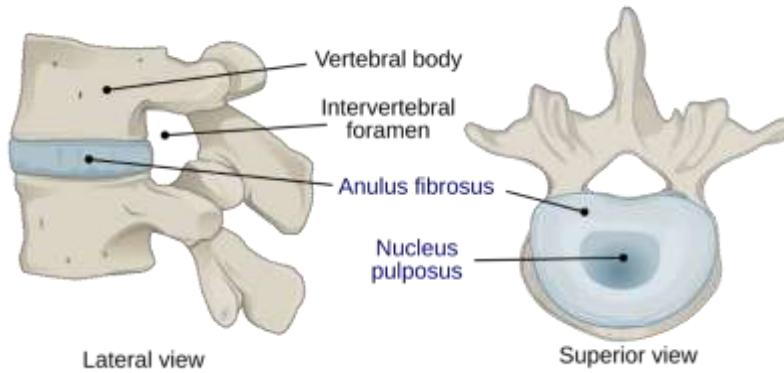


Figure 2: Lateral and superior view of a vertebral body. The two main components of the intervertebral disc are labeled above: Anulus fibrosus and Nucleus pulposus.

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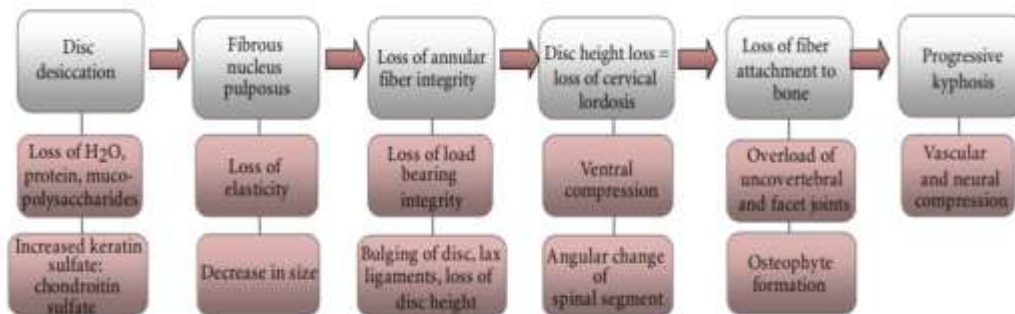


Figure 3: Pathophysiological and biomechanical pathway of cervical spondylosis suggested by Ferrara, L (2012). Displayed are some underlying causes of intervertebral disc height loss that can lead to compression of nerve roots.

Prevalence & Economic consequence

Prevalence and incidence of cervical radiculopathy

A recent systematic review investigated the prevalence and incidence of CSR (Mansfield et al., 2020). The study populations were diverse and included participants from the United States, Egypt, Iran, United Kingdom, and Italy. Data from 13,869,818 participants were evaluated in general population, elite sport, neurology department patients, and a military population. The results of 3 studies indicated the incidence of cervical spine radiculopathy in adults (over 18 years) ranged between 0.83 and 1.79 per 1,000 person-years. The point prevalence values in 3 studies ranged from 1.3 to 5.8 per 1,000. One study reported a 12-month period prevalence of CSR as 1.21 per 1000 people (121/100000). Additionally, 1 study reported that the point prevalence of cervical spine radiculopathy was 1.1% (95% CI: 0.45-1.82) and 1.3% (95% CI: 0.66-1.96) for males and females, respectively. The final study reported an unadjusted point prevalence of 6.3% for male and females.

One widely cited study that followed 561 patients from 1976 to 1990, estimated the annual age-adjusted incidence of cervical radiculopathy to be 83.3 per 100,000 population. The annual male, female, and total rates were 107.3, 63.5, and 83.2 per 100,000 persons, respectively. The 50-54 year age group reported the highest incidence rate at 202.9 per 100,000 persons (Radhakrishnan et al., 1994).

The World Health Organization (WHO) projects that by 2050, 2 billion people will be 60 years and older (*Ageing*, n.d.). Presently, there are approximately 1 billion people 60 years and older. Due to the higher incidence of cervical radiculopathy in older individuals,

it is important to consider the possibility that an aging population may extend to an increase in cervical radiculopathy, and subsequent treatments.

Direct cost

Anterior cervical discectomy and fusion (ACDF) surgery is the gold standard operative procedure for individuals experiencing cervical radiculopathy (Ban et al., 2016). From hospital admission to discharge, treatment costs accumulate in accordance with hospital stay, instrumentation used, and other operative factors (e.g. operating room time). A cost analysis study compared direct costs of 2 different multi-level ACDF procedures for individuals with degenerative disk disease (Castro et al., 2000). The control procedure was ACDF using autologous iliac crest bone graft and anterior plate instrumentation. The comparison procedure was ACDF using titanium surgical mesh cage, local autologous bone graft and anterior plate instrumentation. The total costs consisted of the (summed) titanium surgical mesh cost, operating room costs, and hospitalization costs. The comparator procedure cost estimates ranged from \$5406 to \$6739 USD (Without and with hospitalization costs). The control procedure cost estimates ranged from \$5364 to \$7736 USD (Without and with hospitalization costs).

Another study comparing 4 different ACDF techniques for individuals with cervical degenerative disc disease (with single-level cervical radiculopathy) assessed the cost effectiveness of the operation. The reported costs encompassed implant cost, theater time, and hospital bed cost. The costs ranged from €1,930-2,920. The study concluded that the cage only ACDF technique was the most cost effective surgery (Bhadra et al., 2009).

The cage only ACDF technique had the shortest operative time (90mins) and cost the least (€1,930).

Treatment options

CSR is typically treated with non-operative management. Patients will normally be directed to try conservative treatments for 1-3 months to relieve radicular pain. Non-operative management includes nonsteroidal anti-inflammatory drugs (NSAIDs), muscle relaxants, corticosteroids, and physical therapy exercise programs (Rao et al., 2007).

Exercise programs are commonly used to treat patients experiencing neck or back pain (Amiri Arimi et al., 2017). Exercise programs focus on strengthening the relevant muscles around areas of pain in the body. The efficacy of exercise programs for cervical radiculopathy was evaluated in a systematic review of randomized control trials. Studies in the review compared exercise programs to other forms of non-operative treatment. The other forms of non-operative treatment include ultrasound and infrared radiation, cervical collar, conventional treatment, massage, and acupuncture. The meta-analysis indicated that the exercise groups reduced their pain (VAS) and improved their neck disability (NDI) in comparison to the other forms of non-operative treatment (Liang et al., 2019).

Following conservative treatment for cervical radiculopathy, one study reported approximately 88% of patients achieved complete remission or mild, nondisabling symptoms requiring no treatment (Swezey, 1999).

Operative interventions are considered when the patients' symptoms do not improve after receiving conservative treatment. Two operative procedures are typically considered. The first option is ACDF, the other option is posterior laminotomy-

foraminotomy (Rao et al., 2007). The anterior approach is the treatment of choice for patients with CSR requiring surgical intervention (Whitecloud, 1999)(Kani & Chew, 2018).

ACDF procedure and background

ACDF is a surgical procedure that has been utilized for over 60 years (Smith & Robinson, 1958). ACDF is an effective and minor risk procedure, that has shown high success rates (83-100%) in single and multilevel surgeries (Papadopoulos et al., 2006; Samartzis et al., 2005). The anterior approach begins with a linear incision in the anterior neck, typically within a skin crease. The surgeon then dissects the platysma muscle to reach the subcutaneous tissue and the prevertebral fascia. The fascia is opened to reveal the cervical vertebral bodies. Once the desired disc and vertebrae are identified, the surgeon will remove all disc material and the posterior longitudinal ligament to decompress the nerve. To enable adequate fusion, the cortical bone is removed, and cancellous bone is exposed. This cancellous bone (or spongy bone) is required for fusion with the graft. The graft can be from a separate donor or cadaver (allograft) or from the patients own iliac crest (autograft). The graft is placed into the disk space and imaging can be used to ensure accurate placement. Hardware such as plates and screws are inserted into the patients' vertebrae. Muscle and tissue incisions are then closed up with sutures (Fowler et al., 2005).

How is Neck Pain & Disability Measured?

Neck Disability Index

What is it?

Patients with cervical radiculopathy often experience neck pain, arm pain, and pain-related disability. The most common outcome measure for neck pain-related disability is the Neck Disability Index (Vernon, 2008). The Neck Disability Index was published in 1991 (Vernon, 2008) and was modelled around the Oswestry Low Back Pain Index. The NDI is a 10-item self reporting instrument used to assess individuals' level of neck pain-related disability. Each item has a corresponding 6-point scale that ranges from 0 (No disability) to 5 (Full disability). 7 items are related to activities of daily living, 2 items are related to pain and 1 is related to concentration. The items include pain, personal, care, lifting, reading, headaches, concentration, work, driving, sleeping and recreation (Mjåset et al., 2020). The responses are recorded, and the numeric values associated with the answers are summed to provide a total score out of 50. The total score is converted to a percent ranging from 0-100, where lower scores indicate less neck disability, and higher scores indicate more neck disability. The NDI scores before converting to a percent are interpreted as: 0-4 = no disability; 5-14 = mild disability; 15-24 = moderate disability; 25-34 = severe disability; over 34 = complete disability.

Minimal detectable change (MCD) & Minimal clinically important change (MCIC)

There is error in all measurement instruments. Due to the possible error, a concept called minimal detectable change (MDC) was established. MDC is the minimal change that exceeds the measurement error in an instrument used to measure a given characteristic or symptom (Kovacs et al., 2008). The MDC is useful in distinguishing between change due to within-subject variability or measurement error and true change.

Minimal clinically important change (MCIC) was also established to include patient-oriented improvement. The MCIC identifies the minimum level of change

perceived as important by the patient, regardless of statistical significance. The MCIC is used for comparing outcome values at different time points in patients who received a treatment. The post-treatment outcome values (i.e. NDI) can be compared to baseline measurements. For example, meeting the MCIC threshold in post-treatment NDI values would indicate the patient has demonstrated the smallest change in score that would be perceived by the patient as important. MCIC across patients experiencing acute pain is varied greatly. One systematic review found that absolute MCIC's ranged from 8 to 40mm on the visual analog scale which is a pain measurement instrument, similar to the numeric pain rating scale (Olsen et al., 2017). This systematic review reported relative MCIC's of 13% to 85% in 14 studies.

Various studies have assessed the MDC and MCIC of the NDI in patients with cervical radiculopathy. Young (2010) reported a MDC of 13.4 points. Cleland (2006) reported an MDC of 10.2 for the NDI. Cleland (2008) later reported the NDI's MDC to be 19.6-percentage points in patients experiencing mechanical neck pain undergoing 1 physiotherapy session.

Young (2010) reported a MCID of 8.5 points. A MCID range of 2.72- 12.08 points for the NDI was the reported in another study (Auffinger et al., 2014). Cleland (2006) reported an MCID of 7 points. Cleland (2008) later reported the NDI's MCIC to be 19-percentage points in patients experiencing mechanical neck pain undergoing 1 physiotherapy session.

Reliability & Validity

Reliability

Cleland et al. (2006) assessed the test-retest reliability and construct validity of the NDI. A cohort of 38 patients undergoing physical therapy for cervical radiculopathy was used for the evaluation. Cleland reported the NDI to have a moderate level of reliability (Intraclass correlation coefficient=0.68) and poor construct validity. Cleland (2008) later reported an ICC of 0.5 in a study of 137 patients experiencing mechanical neck pain who underwent 1 session of physiotherapy. This ICC infers a fair reliability measure of the NDI in reference to Shrout's (1998) revised criteria. Young (2010) reported that the NDI had only fair test-retest reliability (ICC= 0.55).

Validity

Construct validity was assessed by comparing the initial (baseline) scores to the follow-up scores in both the stable group and improved group. Results of 1 study indicated that the NDI failed to distinguish between two groups of patients undergoing manual therapy for cervical radiculopathy, a stable and improved group. No significant difference was found between the stable and improved group (Cleland et al., 2006). Resulting in poor construct validity. However, Young's findings for construct validity were not consistent with Cleland et al (2006). Young reported that the NDI showed significant changes in disability which supports the construct validity of the NDI.

The construct validity of the NDI was assessed again by Cleland (2008). Patients that identified as improved after their physiotherapy session had significant reductions in disability in comparison to the patients identified as stable. The results indicated that the NDI does exhibit adequate construct validity.

A systematic review analysing 37 studies concluded that the NDI is a reliable, valid and responsive measurement tool. The review included different patient populations such as whiplash-associated disorders and cervical radiculopathy (MacDermid et al., 2009).

Numeric Pain Rating Scale

The numeric pain rating scale (NPRS) is a self-reported pain rating questionnaire used to measure the intensity of pain. The scale ranks 11 items 0-10, 0 being no pain and 10 being worst pain imaginable. One thing to consider when using the NPRS is subjective difference between sexes. For example, a male may under report their pain whereas a female may over report their pain. Moreover, a males 10/10 pain could be more intense than a females 10/10 pain.

Young (2010) reported a NPRS MDC of 4.1 in patients with cervical radiculopathy. The MCD for the NPRS was reported to be 2.1 points in patients experiencing mechanical neck pain undergoing 1 physiotherapy session (Cleland et al., 2008).

Young (2010) reported a NPRS MCID of 1.3 to 2.2 points in patients with cervical radiculopathy. The MCID for the NPRS was reported to be 1.3 points in patients experiencing mechanical neck pain undergoing 1 physiotherapy session (Cleland et al., 2008).

Reliability

Young (2010) followed a group of patients (n=165) with cervical radiculopathy. This group underwent physical therapy for approximately 4 weeks. The authors found a moderate level of reliability with the NPRS (ICC= 0.63). In another study a group of 89 patients experiencing mechanical neck pain were identified as being stable after one

physiotherapy session. This group was used to evaluate the reliability of the NPRS using test-retest procedure which reported an intraclass correlation coefficient (ICC) of 0.76. The ICC supports the claim that the NPRS is moderately reliable measurement tool (Cleland et al., 2008), (Shrout, 1998).

Validity

In Youngs (2010) study, the NPRS exhibited construct validity. The authors compared patients' baseline values to their follow-up values in stable and improved groups. The construct validity of the NPRS was also assessed by Cleland (2008). Patients that identified as improved after their physiotherapy session had significant reductions in disability in comparison to the patients identified as stable. The results indicated that the NPRS does exhibit construct validity.

Measurement properties for outcome success

The outcomes of interest for our research topic encompass both pain and disability. The NDI will measure the degree of neck disability. The NPRS-arm pain will assess arm pain severity and the NPRS-neck pain will assess neck pain severity.

Post-operative success can be indicated by cut-off values. A cut-off value determines the outcome threshold value in which patients' surgical outcomes are deemed a failure or success. One study investigated patients undergoing surgery for cervical degenerative radiculopathy. Patients were followed up at 3- and 12-months post-surgery. The results of the study reported change scores and percentage change scores of the NDI, NPRS-arm pain, and NPRS-neck pain. The advantage of using percentage change scores is individuals baseline scores are included as opposed to the absolute difference in scores.

The NDI change score and percentage change score for the subgroup undergoing ACDF (or ACD and arthroplasty) was 13.5 and 36.3% respectively. The NPRS-arm pain change score and percentage change score for the anterior approach subgroup was 2.5 and 47.2% respectively. The NPRS-neck pain change score and percentage change score for the anterior approach subgroup was 1.5 and 35.4% respectively (Mjåset et al., 2020).

Predictors

Despite the importance of preoperative predictors of postoperative outcomes, there is currently a small body of research on preoperative predictors outcome success following ACDF surgery. Predictors are important to identify for clinicians performing surgery. Each patient can have different prognostic factors that contribute to the trajectory of postoperative pain and disability.

Predictors

Five studies have evaluated predictors of surgical outcome following ACDF. The categories of predictors included demographics, physical capacity, pain and disability, smoking and narcotic use, and psychosocial.

Demographic predictors comprised of age, sex, and education. Male sex was prospectively associated with successful surgical outcomes in 3 studies. Additionally, 1 study found a prospective association for older age and education as good predictors of surgical outcomes (Hermansen et al., 2013; Peolsson et al., 2003; Peolsson & Peolsson, 2008). Younger patients have evidence of better postoperative outcomes in other studies (Bertalanffy & Eggert, 1988; Eriksen et al., 1984).

Physical capacity is another category of predictors. 2 prospective studies reported that hand strength, greater segmental kyphosis, and active range of motion of the neck were good predictors of surgical outcome (Peolsson et al., 2003; Peolsson & Peolsson, 2008).

Pain- and disability-related predictors were evaluated in 2 retrospective and 4 prospective studies. Low pain frequency predicted good outcomes in 1 study. The remaining predictors had conflicting results. Higher preoperative NDI scores predicted overall clinical success in one study (Anderson et al., 2009). In comparison, lower NDI scores have been reported to predict good long-term outcomes of pain intensity and NDI following surgery (Peolsson & Peolsson, 2008). Moreover, 1 study reported that high pain intensity predicted good surgical outcomes because of the larger difference of pre and post-operative pain (Hermansen et al., 2013). In contrast, 2 studies showed that low pain intensity predicted good surgical outcomes (Peolsson et al., 2003; Peolsson & Peolsson, 2008). A retrospective cohort study found that normal sensory function predicted good outcome success in patients experiencing cervical radiculopathy (Anderson et al., 2009).

Smoking and narcotic use was another category of predictors that was found in the literature. Weak narcotic use and smoking were both found to be poor predictors of surgical outcomes in 1 retrospective and 4 prospective studies respectively (Anderson et al., 2009; Hermansen et al., 2013; Peolsson et al., 2003, 2006; Peolsson & Peolsson, 2008).

There were 2 studies that assessed the psychosocial factors that contributed to outcome success. Workers' compensation was predictive of poor surgical outcomes in one retrospective study. Furthermore, normal distress levels were prospectively associated with a low NDI score postoperatively (Peolsson et al., 2006).

Gaps in Literature

Clinical outcomes following ACDF surgery for CSR can vary from patient to patient. Identifying potential predictors of poor outcomes following surgery for CSR can help inform optimal patient selection for clinicians. The role of other common pre-operative treatments remains unknown.

The aim of this research is to first identify the association between common preoperative therapies and pain and disability following ACDF surgery. The second aim is to investigate the causal effect of predictors by controlling for potential confounding variables. The pre-operative factors to be investigated are anti-convulsant and opioid medications, spinal injections, pre-operative physiotherapy and chiropractic treatment, and regular exercise.

The knowledge gained by our study will assist surgeons with therapy selection and help to set appropriate outcome expectations for patients. This information can help identify those patients most likely to benefit from ACDF surgery. In the long term, this line of research may help to inform health policy and resource allocation through improved clinical outcomes and reduction of unnecessary surgery.

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The Role of Preoperative Therapies in Recovery from Anterior Cervical Discectomy and Fusion Surgery for Cervical Radiculopathy

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Key Words: Prognostic factors; prediction; cervical radiculopathy; neck surgery; anterior cervical discectomy and fusion; pain; disability; outcome; recovery; physiotherapy; exercise; chiropractor; opioids; anti-convulsant; spinal injections

Level of Evidence: 2

Mini Abstract/Précis

We explored associations between common preoperative therapies and pain/disability outcomes following anterior cervical discectomy and fusion surgery for cervical radiculopathy. In this longitudinal study of prospectively collected data, approximately 20% of patients experienced poor outcome. Daily opioid use, spinal injections, physiotherapy and regular exercise were predictive of outcome.

ABSTRACT

Study Design: Longitudinal study of prospectively collected data.

Objective: Objective one is to explore for associations between the use of preoperative therapies postoperative trajectories of pain and disability. Study objective two is to estimate the effect of these preoperative therapies on postoperative trajectories of pain and disability after controlling for potential confounders.

Summary of Background Data: Cervical Spondylotic Radiculopathy is a neck disorder caused by compression and/or inflammation of cervical nerve roots leading to pain and disability of the neck and arms. The role of preoperative therapies on outcomes following anterior cervical discectomy and fusion surgery is unknown.

Methods: Surgical candidates were from 12 orthopaedic and neurological surgical centers across Canada. The preoperative therapies investigated are anti-convulsant and opioid pain medication, spinal injections, physiotherapy and chiropractic treatment, and regular exercise. Study outcomes include neck pain (NPRS), arm pain (NPRS), and neck pain-related disability (NDI) measured preoperatively and 3, 12, and 24 months post-

surgery. Trajectories of pain and disability were modeled over time, with participants fitted into subgroups using latent-class growth analysis. Associations between preoperative prognostic factors and trajectory group membership will be investigated using robust Poisson models.

Results: Data from 352 patients (mean [SD] age= 50.85[9.52] years; 43.8% female) are included. In total 15.5%, 23.2%, and 23.5% of patients are classified as experiencing a poor neck disability, neck pain, and arm pain outcome respectively. Univariable results showed that daily opioid use was associated with poor neck disability outcome.

Additionally, spinal injections, physiotherapy, and regular exercise were predictive of good outcome. Furthermore, multivariable results demonstrated spinal injections, physiotherapy, and regular exercise had a causal effect on neck disability outcome after controlling for age, sex, baseline pain (or disability) levels, and education.

Conclusion: Approximately one out of five patients with cervical radiculopathy experience poor outcome following ACDF. Common preoperative therapies show predictive ability and have causal effects on postoperative outcome. These preoperative variables can help inform future healthcare policies and identify optimal surgical candidates.

Key Points

- This longitudinal study of 352 patients with cervical radiculopathy undergoing anterior discectomy and fusion surgery had approximately 1 in 5 patients experience a poor postoperative outcome.
- Daily opioid use, spinal injections, physiotherapy, and regular exercise were predictive of neck disability outcome.
- Identifying important preoperative therapies that predict or cause certain outcome may help surgeons select optimal surgical candidates with cervical radiculopathy.

Chapter 2: Introduction

Cervical Spondylotic radiculopathy is a common condition that describes compression and inflammation of nerve roots near the cervical neural foramen. Point prevalence of cervical spondylotic radiculopathy ranges from 1.3 to 5.3 per 1,000 people along with incidence ranging between 0.83 and 1.79 per 1,000 person-years (Mansfield et al., 2020). Cervical spondylotic radiculopathy presents symptomatically as pain in the neck and arms. Compression of the cervical nerve roots can also result in the loss of motor or sensory function in the affected dermatome or myotome. (Finnerup et al., 2016)

Anterior cervical discectomy and fusion (ACDF) surgery is currently the gold standard for operative treatment for patients with cervical spondylotic radiculopathy. ACDF is an effective and safe procedure that has shown high success rates (88 to 100%) in single and multilevel surgeries. (Papadopoulos et al., 2006; Samartzis et al., 2005)

Clinical outcomes regarding ACDF surgery for CSR can vary from patient to patient. Identifying potential predictors of poor outcomes following surgery for cervical spondylotic radiculopathy can help inform clinicians for optimal patient selection. Few studies have investigated predictors of ACDF surgery outcomes. Preliminary evidence shows that smoking, narcotic use, and workers compensation claims predict poor surgical outcomes (Anderson et al., 2009; Hermansen et al., 2013; Peolsson et al., 2003, 2006; Peolsson & Peolsson, 2008). Moreover, some evidence suggests that male sex, normal sensory function, greater neck range of motion and segmental kyphosis, low pain intensity and frequency, and greater hand strength are predictive of good postoperative outcomes

(Anderson et al., 2009; Hermansen et al., 2013; Peolsson et al., 2003, 2006; Peolsson & Peolsson, 2008). There are conflicting results regarding predictors of outcome such as preoperative NDI scores, and older age. (Bertalanffy & Eggert, 1988; Eriksen et al., 1984; Peolsson et al., 2003)

A trial of non-operative treatment is advised prior to surgical consultation. However, the role of common non-operative treatment in subsequent surgical outcomes remains unknown. Therefore, the aim of this study is to identify the role of common preoperative therapies in recovery following ACDF surgery. Specifically, study objective one is to explore for associations between the use of preoperative anti-convulsant and opioid pain medications, spinal injections, regular exercise, physiotherapy and chiropractic treatment, with postoperative trajectories of pain and disability. Study objective two is to estimate the effect of these preoperative therapies on postoperative trajectories of pain and disability after controlling for potential confounders.

Methods

Study design and participants

We analysed data from patients enrolled in the Canadian Spine Outcomes and Surgical Network (CSORN). The CSORN project is a multicenter, nationwide initiative to define surgical outcomes for patients undergoing spinal surgery. This study is a longitudinal analysis of prospectively collected data from 352 patients. We included data from all adult patients (18+ y/o) with a primary pathology of cervical spondylotic radiculopathy who

underwent anterior cervical discectomy and fusion surgery. We excluded patients with cervical myelopathy, previous neck surgery, tumour, infection, or inflammatory arthritis. The primary pathology and type of surgery were reported by the treating spine surgeon. Clinical outcomes were measured preoperatively, and 3, 12, and 24 months after surgery.

Ethics approval

The nationwide CSORN project was approved at each spine center by their local Research Ethics Boards. Ethical approval for the current analysis was provided by the Horizon Health Network (2019-2797) and the University of New Brunswick (2019-161) research ethics board. All patients provided written informed consent to participate before study enrolment.

Potential predictors

Patients completed standardized health assessment forms and questionnaires to collect individual demographic, health-related, and clinical information to include preoperative treatment. Patients' preoperative assessment data were collected with a self-reported questionnaire and entered by research staff into the CSORN surgical registry. We investigated six preoperative treatment factors including anti-convulsant and opioid pain medications, spinal injections, physiotherapy treatment, chiropractic treatment, and exercise. Patients self-reported their use of preoperative treatment factors. Patients were asked about opioid and anti-convulsant medication use related to their neck or arm pain. Specifically, data was collected on the frequency (e.g., not taken, taken as needed, or daily)

over the last 6 months prior to surgery. For current symptoms, spinal injection (with or without x-ray control) frequency (0, 1, 2, 3, >3 times or not sure) over the last 6 months prior to surgery was documented. Physiotherapy and chiropractic treatment frequency (0, 1-2, 3-30, and >30 times) was documented over 6 months prior to surgery. Finally, exercise was defined as 20 minutes or more of nonstop activity (e.g., swimming, jogging, rapid walking, cardio, and weights/resistance). Exercise was self-reported in two ways; how often one exercises per week (never- due to physical limitations, never, ≤ 1 or ≥ 2 times per week or choose not to answer) and engagement in habitual exercise (<6 mo, 6-12 mo, 1-2 yrs, and >2 yrs).

Outcomes

Patient reported outcomes for pain and disability of the neck and arms were measured preoperatively, and 3, 12, and 24 months after surgery. Outcomes of interest are pain intensity of the neck and arms measured with separate Numeric Pain Rating Scale (NPRS) and neck pain-related disability measured using the Neck Disability Index (NDI). The NPRS ranges from 0 (no pain) to 10 (worst pain imaginable). The NDI ranges from 0 to 100; zero indicates no disability and 100 indicates severe disability. These outcomes are reliable and valid in patients with cervical radiculopathy. (Cleland et al., 2008; MacDermid et al., 2009)

The minimum clinically important change (MCIC) for the NPRS-neck pain in patients with cervical spondylotic radiculopathy undergoing ACDF surgery is 1.3 to 2.2 points and a percent change score of 35.4% (Mjåset et al., 2020; Young et al., 2010). The MCIC for

NPRS-arm pain was 2.5 points with a percent change score of 47.2% (Mjåset et al., 2020). The MCIC for neck-related disability ranges from 7 to 13.5 points and a percent change score of 36.3% on the NDI in patients with cervical spondylotic radiculopathy undergoing ACDF surgery (Auffinger et al., 2014; Cleland et al., 2006; Mjåset et al., 2020; Young et al., 2010).

Data analysis

Data analysis was performed in three stages. First, trajectories of pain and disability were identified and modeled over time, with all participants fitted into latent classes using latent class growth models. Each trajectory subgroup contains clusters of patients that followed similar courses of postoperative pain or disability. The details of the trajectory analysis have been reported in depth elsewhere (Hebert *et al.*, in preparation). Second, associations between preoperative therapies and trajectory group membership for each outcome (NDI, NPRS-arm, NPRS-neck) were examined using univariable robust Poisson regression models for all 6 predictors in each outcome measure. We additionally constructed multivariable robust Poisson regression models, adjusted for age, sex, education, and baseline pain or disability levels. Poisson regression models were used for our binary outcomes as opposed to logistic regression due to an inflated odds ratio when working with non-rare outcomes (i.e., greater than 10%) (Chen et al., 2018). Cluster effects around individual surgeons were considered by using mixed-effects robust Poisson regression with the surgeon entered as a random effect. We compared the mixed-effects and fixed-effects models with a likelihood ratio test and identified no between model differences. Moreover,

there were only minimal differences between parameter estimates. Therefore, we elected to report the simpler (fixed effects) model results. All model outcomes were reported with incidence rate ratio (IRR) and 95% confidence interval (CI).

We conducted sensitivity analyses by calculating E-values for each significant multivariable model result (Mathur et al., 2018; VanderWeele & Ding, 2017). The E-value quantifies unmeasured confounding by estimating the magnitude of the unknown confounder's association (on the risk ratio scale), with the exposure and the outcome, needed to explain away the results. In other words, the resulting E-value is the magnitude of association for an unmeasured confounder required to move the confidence interval to include the null. We calculated E-values for both the parameter estimate and the lower bound of its confidence interval. All analyses were performed with Stata 16 software (StataCorp, College Station, TX, USA).

Results

Our total sample size comprised 352 patients (43.8% female) from 12 neurological and orthopedic surgical centers across Canada with a mean (SD) age of 50.9 (9.5) years. Sample sizes for our trajectory models ranged from 329 to 342. Sample sizes for the regression models ranged from 311 to 342 (Figure 1). Table 1 describes the preoperative demographics, health, clinical and surgical information for the sample population.

The latent class growth models identified 3 patient subgroups who followed pain trajectories that we defined as “excellent”, “good”, and “poor” based on the shape of the

trajectories and the mean magnitude of improvement experienced by patients in each subgroup. Similarly, the disability trajectory model yielded 3 similar subgroups: “excellent”, “fair”, and “poor”. The percentage of patients in the poor outcome trajectory were 15.5% (disability), 23.2% (neck pain), and 23.5% (arm pain) as seen in Figure 3.

Univariable model results

Our univariable model identified 4 preoperative therapies related to ACDF outcome. Patients using daily opioids were about 2 times more likely to have a poor disability outcome compared to patients not using opiates (IRR [95% CI]= 2.05 [1.18 to 3.56]). In contrast, patients who received preoperative spinal injections within 6 months of surgery, had a 52% reduced risk of poor NDI outcome (IRR [95% CI]= 0.48 [0.23 to 0.98]). Patients who received at least one preoperative physiotherapy session were 49% less likely to have a poor NDI outcome (IRR [95% CI]= 0.51 CI [0.30 to 0.88]). Engaging in regular exercise prior to surgery was associated with a 66% reduced risk (in comparison to not regularly exercising) of poor NDI outcome (IRR [95% CI]= 0.44 CI [0.24 to 0.79]). No other preoperative therapies were associated with postoperative outcomes (Figure 2a).

Multivariable model results

After controlling for confounding by age, sex, education, baseline neck pain, arm pain, or disability, 3 preoperative therapies were associated with a lower likelihood of poor disability outcome (Table 3).

Patients who received spinal injections had a 54% reduced risk of poor neck disability outcome (IRR [95% CI]= 0.46 [0.22 to 0.97]). Patients who received preoperative physiotherapy had a 44% reduced risk of poor NDI outcome (IRR [95% CI]= 0.56 [0.33 to 0.96]). Patients who engaged in regular exercise at least 6 months preoperatively had 50% reduced risk of poor neck disability outcome (IRR [95% CI]= 0.50 [0.27 to 0.89]). All other preoperative therapy variables were not associated with clinical outcomes in the multivariable models (Figure 2b). The E-values computed for point estimates were: spinal injections (3.77), physiotherapy (2.97) and regular exercise (3.45). The E-values for the confidence intervals were: spinal injections (1.21), physiotherapy (1.25) and regular exercise (1.48).

Discussion

Our study aimed to investigate potential predictors of poor outcome following ACDF surgery, and estimate the effect of these preoperative therapies on postoperative trajectories of pain and disability. In our Canada-wide sample of patients who underwent ACDF surgery for cervical spondylotic radiculopathy, 15.5 to 23.5% of patients experienced a poor clinical outcome. We found 4 preoperative therapies that predicted outcome following ACDF (Table 2). Daily opioid use was associated with approximately 2 times higher risk of a poor neck disability outcome after ACDF surgery. Furthermore, spinal injections, physiotherapy, and regular exercise had protective association of poor neck disability outcome.

After controlling for age, sex, baseline pain or disability, and education, three variables demonstrated an effect on postoperative disability. Preoperative spinal injections, physiotherapy and regular exercise reduced the risk of poor neck disability outcome (Table 3). We acknowledge there may be other confounding variables not identified that could explain outcome. Therefore, we conducted a sensitivity analysis to reinforce our confidence that these variables were affecting the outcome measure (Mathur et al., 2018; VanderWeele & Ding, 2017). With spinal injections, physiotherapy, and regular exercise, we observed an IRR of 0.46, 0.56, and 0.50 respectively. With these IRR's, an unmeasured confounder would have to be associated with the outcome and exposure variable with an IRR of 3.97, 2.97, and 3.41 respectively to explain away the estimate, however weaker confounding could not. Furthermore, to move the confidence interval to include the null, an unmeasured confounder that's associated with both outcome and exposure variable would have to be 1.21, 1.25, and 1.46 respectively (VanderWeele & Ding, 2017). The calculated E-values for our estimates and confidence intervals provides a moderate amount of confidence that these variables are truly affecting outcome. In comparison to all the significant variables IRRs, an unknown confounder required IRR association of 3-4 is quite large.

Weak narcotic use has previously been reported to be a negative predictor of overall clinical success in another study (Anderson et al., 2009). There are few studies on predictors of outcome for ACDF surgery, and none to date on preoperative therapies specifically. However, some studies have reported predictors of outcome following other spinal surgeries such as lumbar spinal stenosis (LSS) (Hébert et al., 2020). Preoperative

therapies like chiropractor treatment, physiotherapy and regular exercise all predicted a good overall outcome following LSS. Moreover, anticonvulsant medication use predicted poor leg pain outcome, while regular exercise predicted a good leg pain outcome. There is anatomical difference between the cervical and lumbar spine however these are the most relevant findings regarding the role of preoperative therapies and spine surgeries.

Our study had various strengths and weaknesses which inform the interpretation of the study results. Strengths of our study include the relatively large and geographically diverse patient representation. Through the CSORN database, we were able to assess patients across Canada. This helps improve the generalizability of our study results. Furthermore, we utilized patient reported outcome measures (PROMs) for our analysis. By shifting measures to focus on the patient's perspective as opposed to the surgeons rating of surgical effectiveness, we gain a more accurate understanding of the condition's prognosis. Weaknesses identified in our study include subjective reporting of preoperative variables. Patients may not be willing to disclose certain information on the provided questionnaires, such as opioid use. In future studies, objectively collecting medication use can avoid this limitation. Moreover, the information collected on therapies such as physiotherapy or chiropractic therapy was not in depth. This means we don't know key information on their sessions such as duration, intensity, solo Vs group sessions and specific exercise performed. Lastly, the regular exercise variable collected from the questionnaire was not very descriptive. Considering the significant preoperative variables identified were regular exercise, daily opioid use, and physiotherapy, knowing these pieces of information could further our understanding on causal mechanisms.

Clinical implications

It is evident that approximately 1/5 of patients undergoing ACDF stay at a relatively high level of pain or disability (Figure 3). The result of this study highlights some key take aways for healthcare providers and patients. We have identified various predictors of bad outcome. Furthermore, our multivariable models have set up the use of causal language for certain variables. Our study found preoperative therapies that can predict outcome which surgeons and other healthcare providers may wish to consider when selecting optimal surgical candidates. The causal model results support the hypothesis that receiving preoperative therapies reduces risk of poor outcome. Although practice guidelines recommend that patients with spinal disorders undergo conservative therapies prior to surgery, many patients do not receive these therapies (Appendix A, Table A). Surgeons may want to reconsider operating on patients that have not exhausted these preoperative therapies.

Research implications

Future research in this area should consider conducting a multivariable prognostic model. This consists of combining multiple prognostic factors (i.e., smoking, BMI, and exercise) identified in this study with other prognostic factors identified in other study to better understand the role of preoperative therapies in predicting surgical outcomes following ACDF. More comprehensive research involving directed acyclic graphing should be conducted to further our understanding of causation. Additionally, randomized clinical trials for preoperative therapies such as physiotherapy and regular exercise should be

developed. Due to the nature of this study, the observational data can only provide part of the causal picture however a randomized clinical trial investigating these variables could uncover a greater understanding of causal mechanisms.

Conclusion

ACDF surgery is the gold standard operative treatment for individuals with problematic cervical spondylotic radiculopathy. It's the authors understanding that to date, no study has investigated the role of common preoperative therapies for patients receiving ACDF. Our study has uncovered multiple preoperative therapies that have prognostic predictive ability and even causal effect on patient reported outcome measures following surgery. This information may assist future surgeons in optimal candidate selection and inform future health policy.

Figures

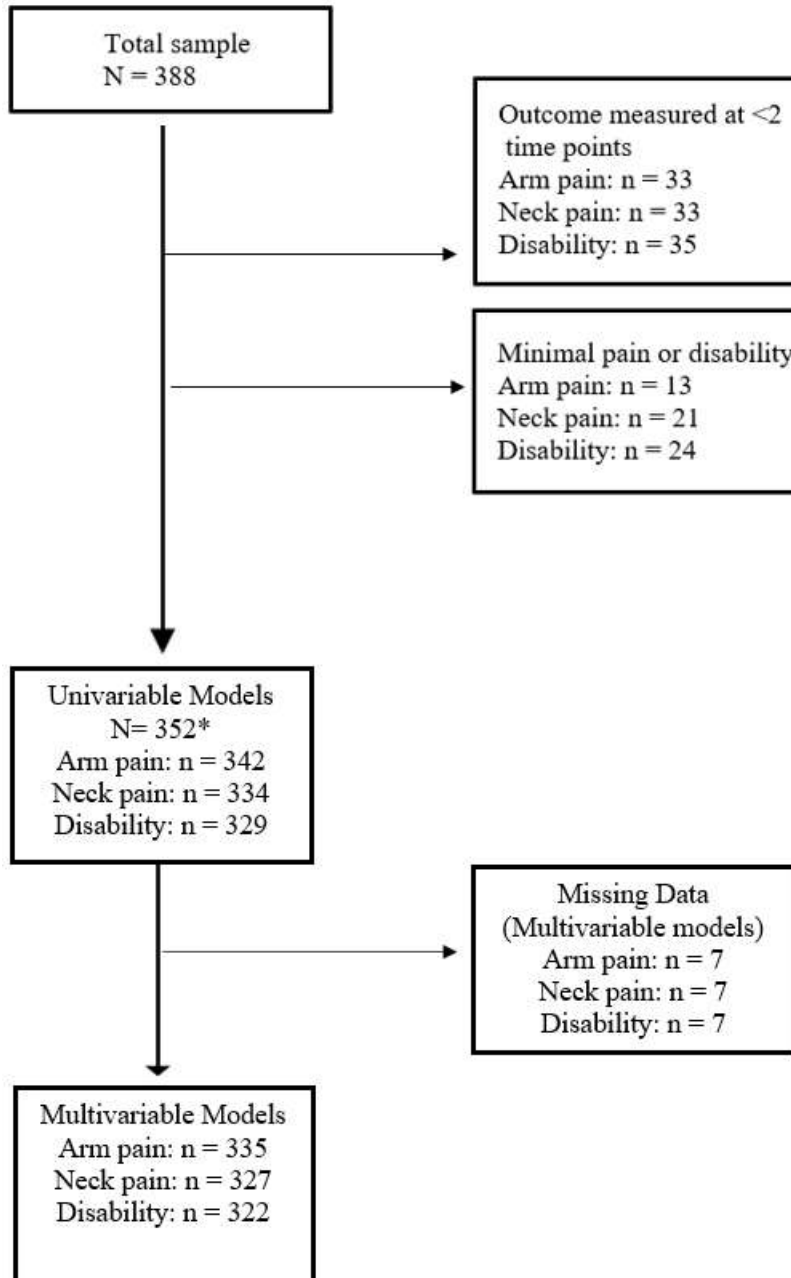


Figure 1: Study flow diagram. *Patients included in one or more outcome models.

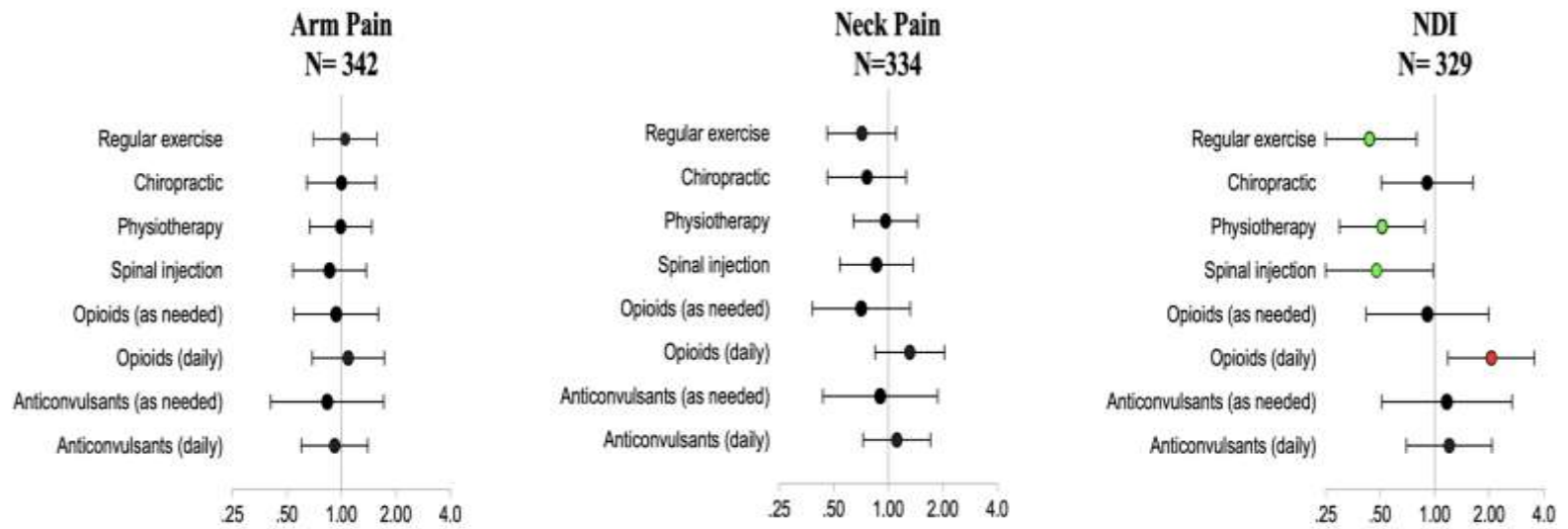


Figure 2a: Univariable Forrest plot. The x-axis represents incident risk ratio. Green circles are significant protective association of poor neck disability outcome. Red circles are significant predictors of poor neck disability outcome.



Figure 2b: Multivariable Forrest plot. The x-axis represents incident risk ratio. Green circles are significant preoperative therapy variables in an adjusted multivariable model controlling for age, sex, education, and baseline pain or disability.

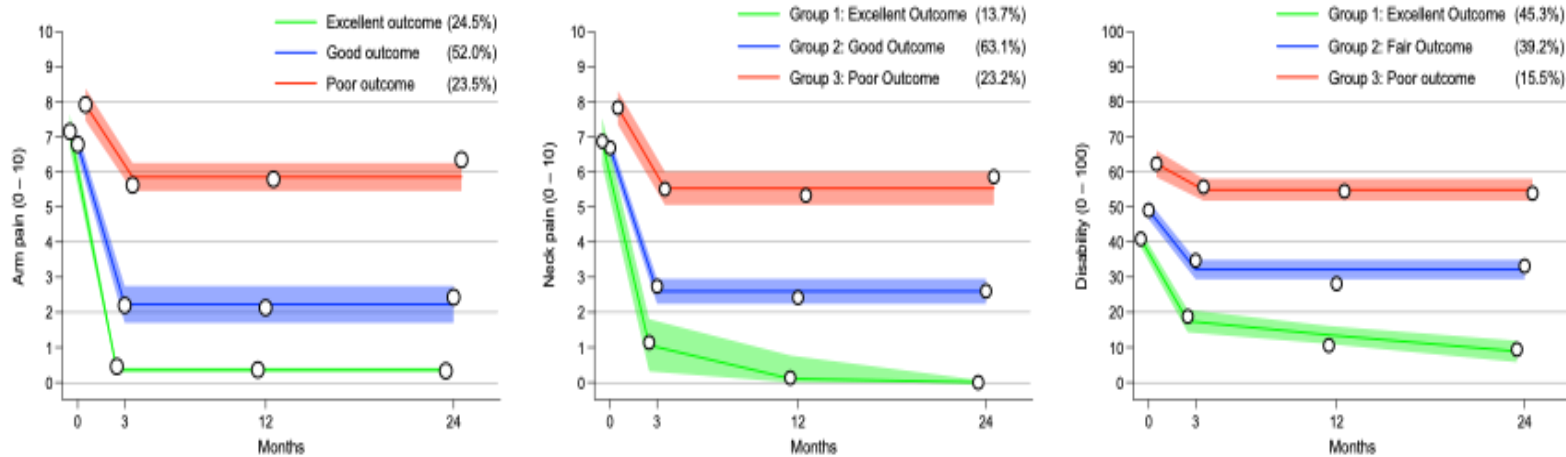


Figure 3: Group-based trajectories. Each graph represents a different outcome measure (NPRS-arm, NPRS-neck, and NDI) with 3 distinct groups. The 3 groups are defined as excellent, good and poor outcome. For the disability outcome, the groups are excellent, fair, and poor outcome due to the smaller improvement of disability

Tables

Table 1. Preoperative characteristics and surgical details (N = 352).

Variable	Sample Size	Value
Age	352	50.85 ±9.52
Female Sex	352	154 (43.75%)
Body mass index	343	29.38 ±5.97
Smokers	343	77 (22.45%)
Workers Compensation	323	99 (30.65%)
Education:		
High School degree or less	346	123 (36%)
Technical School or Associates degree		81 (23%)
Undergraduate degree/graduate degree		142 (41%)
Regular exercise	339	161 (47.49%)
Daily Opioid use	343	96 (27.99%)
Anti-convulsant use	340	134 (39.41%)
Spinal injections	341	99 (29.03%)
Physiotherapy	351	173 (49.29%)
Chiropractic	352	96 (27.27%)
Neurological Deficit:		
No deficit	351	143 (40.8%)
Sensory function deficit		73 (20.8%)
Motor function deficit		29 (8.3%)
Motor and Sensory deficit		106 (30.2%)
Surgical Variables		
Time with condition		
Less then 6 months	351	54 (15.4%)
6 months to 1 year		52 (14.8%)
1 year to 2 years		80 (22.8%)
Over 2 years		165 (47%)
Previous spine surgery	352	67 (19%)
Estimated blood loss (ml)	336	85.47 ±96.13
Number of operated spinal levels:		
1 level	352	223 (63.35%)
2 levels		98 (27.84%)
3 levels		24 (6.82%)
more than 3 levels		7 (1.99%)
Surgery duration (min)	321	134.8 ±72.5

Values indicated number (percent) or mean ±SD. Preoperative therapy variable values are the number of individuals that did receive the treatment. BMI value is the number of individuals that are classified as obese (BMI >30).

Table 2. Final univariable robust Poisson models of factors associated with poor outcome following ACDF surgery.

Predictor	N	Incident Rate Ratio (95% CI)	P-value
NDI outcome (N= 329)			
Daily Opioid Use*	320	2.05 (1.18 to 3.56)	0.011
As needed Opioid Use	320	0.91 (0.42 to 1.99)	0.817
Daily Anti-convulsant Use	318	1.2 (0.70 to 2.07)	0.505
As needed Anti-convulsant Use	318	1.67 (0.51 to 2.67)	0.715
Spinal Injections*	318	0.48 (0.23 to 0.98)	0.044
Physiotherapy*	328	0.51 (0.30 to 0.88)	0.015
Chiropractor	329	0.91 (0.51 to 1.63)	0.747
Regular Exercise*	316	0.44 (0.24 to 0.79)	0.006
NPRS- arm (N= 342)			
Daily Opioid Use	333	1.09 (0.69 to 1.73)	0.709
As needed Opioid Use	333	0.94 (0.55 to 1.60)	0.809
Daily Anti-convulsant Use	330	0.92 (0.60 to 1.40)	0.693

As needed Anti-convulsant Use	330	0.84 (0.46 to 1.52)	0.557
Spinal Injections	331	0.86 (0.54 to 1.37)	0.530
Physiotherapy	341	0.99 (0.67 to 1.47)	0.967
Chiropractor	342	1.00 (0.64 to 1.55)	0.996
Regular Exercise	329	1.05 (0.70 to 1.57)	0.810
NPRS- neck (N= 334)			
Daily Opioid Use	326	1.32 (0.84 to 2.05)	0.225
As needed Opioid Use	326	0.71 (0.38 to 1.32)	0.279
Daily Anti-convulsant Use	323	1.11 (0.73 to 1.71)	0.613
As needed Anti-convulsant Use	323	0.90 (0.44 to 1.87)	0.785
Spinal Injections	324	0.88 (0.54 to 1.41)	0.565
Physiotherapy	333	0.97 (0.64 to 1.46)	0.874
Chiropractor	334	0.76 (0.46 to 1.26)	0.29
Regular Exercise	321	0.71 (0.46 to 1.11)	0.133

NDI= Neck Disability Index (0-100). NPRS= Numeric pain rating scale (0-10). *Indicates a significant p-value.

Table 3. Multivariable robust Poisson models of preoperative therapies associated with three different outcome measures.

These models were adjusted for age, sex, education, baseline neck or arm pain and disability.

Predictor	N	Incident Rate Ratio (95% CI)	P-value	E-value Point Estimate	E-value Confidence Interval
NDI outcome (N= 323)					
Daily Opioid Use	315	1.45 (0.85 to 2.47)	0.172		
As needed Opioid Use	315	1.00 (0.47 to 2.11)	0.999		
Daily Anti-convulsant Use	313	1.03 (0.60 to 1.75)	0.921		
As needed Anti-convulsant Use	313	1.33 (0.59 to 3.03)	0.493		
Spinal Injections*	313	0.46 (0.22 to 0.97)	0.040	3.77	1.21
Physiotherapy*	322	0.56 (0.33 to 0.96)	0.034	2.97	1.25
Chiropractor	323	1.00 (0.58 to 1.74)	0.989		
Regular Exercise*	311	0.50 (0.27 to 0.90)	0.020	3.41	1.46
NPRS- arm (N= 335)					
Daily Opioid Use	328	0.90 (0.58 to 1.40)	0.642		
As needed Opioid Use	328	0.91 (0.53 to 1.53)	0.713		

Daily Anti-convulsant Use	325	0.82 (0.54 to 1.24)	0.348		
As needed Anti-convulsant Use	325	0.86 (0.42 to 1.76)	0.678		
Spinal Injections	326	0.87 (0.55 to 1.38)	0.567		
Physiotherapy	335	1.04 (0.70 to 1.54)	0.844		
Chiropractor	335	1.04 (0.67 to 1.62)	0.855		
Regular Exercise	323	1.29 (0.86 to 1.93)	0.217		
NPRS- Neck (N= 327)					
Daily Opioid Use	321	0.93 (0.60 to 1.43)	0.729		
As needed Opioid Use	321	0.65 (0.35 to 1.22)	0.181		
Daily Anti-convulsant Use	318	0.95 (0.63 to 1.45)	0.826		
As needed Anti-convulsant Use	318	0.93 (0.43 to 2.01)	0.861		
Spinal Injections	319	0.94 (0.59 to 1.49)	0.781		
Physiotherapy	327	0.96 (0.64 to 1.44)	0.834		
Chiropractor	327	0.81 (0.50 to 1.30)	0.382		
Regular Exercise	315	0.90 (0.57 to 1.38)	0.610		

NDI= Neck Disability Index (0-100). NPRS= Numeric pain rating scale (0-10). *Indicates a significant p-value.

Appendix A

Canadian Spine Outcomes and Research Network (CSORN)

CSORN is a multicentered national spine surgery registry that tracks and reports various spine surgeries, adverse events, and patient reported outcome measures from 21 orthopaedic and neurological surgical centers across the country. CSORN contained more than 11000 patients in 2020. The registry tracks surgical and non-surgical techniques used to treat spine conditions. This network is an effective tool used by surgeons and researchers to closely follow the prognosis of spinal conditions, identify patterns in treatments and recovery, track practice patterns and small area variation, assess treatment effectiveness, and manage resource utilization. CSORN collects both patient and physician reported outcomes. The goal of CSORN is to allow surgeons nationwide to participate in prospective multi-centered trials and retrospective reviews.

Table A: Frequencies (and percentages) of patient responses regarding preoperative therapies from baseline assessment questionnaire.

Preoperative Therapy	Frequency (%)	N=
Opioid use:		332
As Needed	85 (26%)	
Daily	106 (32%)	
Not Taken	133 (40%)	
Unknown	8 (2%)	
Anti-Convulsant use:		332
As Needed	38 (11%)	
Daily	150 (45%)	
Not Taken	133 (40%)	
Unknown	11 (3%)	
Spinal Injections (With X-ray control):		387
0 Times	276 (71%)	
1 Time	59 (15%)	
2 Times	20 (5%)	
3 Times	6 (2%)	
>3Times	15 (4%)	
Unknown	11 (3%)	
Spinal Injections (Without X-ray control):		387
0 Times	359 (93%)	
1 Time	7 (2%)	
2 Times	4 (1%)	
3 Times	1 (0.26%)	
>3Times	3 (0.78%)	
Unknown	13 (3%)	
Physiotherapy:		387
0 Time	195 (50%)	

1-2 Times	38 (10%)	
3-30 Times	129 (33%)	
>30 Times	23 (6%)	
Unknown	2 (0.5%)	
Chiropractor:		388
0 Times	276 (71%)	
1-2 Times	37 (10%)	
3-30 Times	60 (15%)	
>30 Times	10 (3%)	
Unknown	5 (1%)	
Regular Exercise:		388
Chose not to answer	12 (3%)	
Never	42 (11%)	
Never, physical limitations prevent me from exercising	81 (21%)	
Once or less per week	75 (19%)	
Twice or more per week	174 (45%)	
Unknown	4 (1%)	

Preoperative therapies from questionnaire

4. A) How often do you exercise?

(20 minutes or more of nonstop activity: swimming, jogging, rapid walking, cardio, weights/resistance)

- Never, physical limitations prevent me from exercising
- Never
- Once or less per week
- Twice or more per week
- Choose not to answer

B) If you do exercise, how long have you been exercising?

- Less than 6 months
- 6 months to less than 12 months
- 12 months to 2 years
- Greater than 2 years

B) For your current symptoms, please indicate which of the following health care providers you have seen in the last 6 months and indicate approximately how many times you have attended:

Allied Health Professional - <u>in the last 6 months</u>	0 Times	1 - 2 Times	3 - 30 Times	>30 Times
Chiropractor				
Physiotherapist				
Occupational Therapist				
Massage Therapist				
Acupuncturist				
Yoga/Pilates Instructor, Personal Trainer				
Other:				
None of the Above				

C) For your current symptoms, please indicate which of the following imaging, tests and injections you have had in the last 6 months. (Please complete every row)

In the past 6 months I have had...						
Imaging	0 Times	1 Time	2 Times	3 Times	> 3 Times	Not Sure
X-ray						
CT Scan						
MRI						
Bone Scan						
Nerve Test: EMG/Nerve Conduction						
Injections: Spinal Injections WITH X-Ray Control (Nerve, Back pain, Facet block or Other)						
Spinal Injections WITHOUT X-Ray Control (Nerve, Back pain, Facet block or Other)						

C) Medications: please check how often you have taken the medications listed below (Not Taken, As Needed (Sometimes) or Daily) in the last 6 months:

Medication - <u>in the last 6 months</u>	Not Taken	As Needed (Sometimes)	Daily
Over the Counter Ex: Advil (ibuprofen), Aleve (naproxen), Aspirin (ASA), Motrin (ibuprofen), Tylenol (acetaminophen)			
Non-Steroidal Anti-Inflammatory Ex: Arthrotec, Celecoxib, Celebrex, Voltaren			
Muscle Relaxant Ex: Flexeril, Robaxacet, Robaxin			
Narcotic Pain Medication Ex: Demerol, MS Contin, Morphine, Oxycontin, Percocet, Talwin, Tylenol 3			
Anti-Depressant Ex: Celexa, Cipralex, Cymbalta, Elavil, Paxil, Prozac, Wellbutrin, Zoloft			
Neuroleptics (agents to calm nerve pain) Ex: Lyrica, Neurontin, Gabapentin, Rivotril, Tegretol			
Prescription Cannabis			

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