

Diagnosis and Treatment of Cervical Radiculopathy and Myelopathy

Table of Contents

- I. [Cervical Surgery Review Criteria](#)
- II. [Introduction](#)
- III. [Background and Prevalence](#)
- IV. [Establishing Work-Relatedness](#)
 - A. [Cervical Conditions as Industrial Injury](#)
 - B. [Cervical Conditions as Occupational Disease](#)
- V. [Making the Diagnosis](#)
 - A. [History and Clinical Exam](#)
 - B. [Diagnostic Tests and Imaging](#)
 - C. [Selective Nerve Root Blocks](#)
- VI. [Treatment](#)
 - A. [Conservative Treatment](#)
 - B. [Surgical Treatment](#)
 - 1. [Anterior Cervical Decompression](#)
 - 2. [Posterior Procedures](#)
 - 3. [Anterior Cervical Discectomy with Fusion \(ACDF\)](#)
 - 4. [Total Disc Arthroplasty \(TDA\)](#)
 - 5. [Multi-level Surgeries](#)
 - 6. [Hybrid Surgeries](#)
 - 8. [Repeat Surgeries](#)
 - 9. [Intraoperative Monitoring](#)
 - 10. [Pseudarthrosis](#)
- VII. [Adjacent Segment Pathology](#)
- VIII. [Measuring Functional Improvement](#)
- IX. [Postoperative Phase and Return to Work](#)
- X. [References](#)

I. CERVICAL SURGERY REVIEW CRITERIA

A request may be appropriate for	AND the diagnosis is supported by these clinical findings			And this has been done (if recommended).
Surgical Procedure & Diagnosis	Subjective	Objective	Imaging	Conservative care
Surgery (in general) For: neck pain without subjective, objective, and imaging evidence of radiculopathy or myelopathy	Surgery is not covered			
ACDF or TDA Laminotomy Foraminotomy For: Radiculopathy-Single level	Sensory symptoms (radicular pain and/or paresthesias) in a dermatomal distribution that correlates with involved cervical level	Motor deficit OR Reflex changes OR Positive EMG Findings should correlate with involved cervical level.	MRI OR Myelogram with CT scan Abnormal imaging read by radiologist (moderate to severe foraminal stenosis) that correlates nerve root involvement with subjective and objective findings	At least 6 weeks* of conservative care, such as: <ul style="list-style-type: none"> • Physical therapy emphasizing active modalities • Osteopathic manipulation • Chiropractic manipulation • Anti-inflammatory medication • Epidural injections *In the case of clear motor deficit after an acute injury, the 6 weeks of conservative care is not required.
	AND	AND	AND	
		OR	In the case of discordant reading between surgeon and radiologist, an independent radiologist opinion is needed.	
	Sensory symptoms (radicular pain and/or paresthesias) in a dermatomal distribution that correlates with involved cervical level	A positive response to a selective nerve root block, as determined and documented by the interventionist, in the case of complaints of radicular pain without motor, sensory, reflex or EMG changes. Criteria for selective nerve root blocks (see page 8 for details): <ul style="list-style-type: none"> • Use low-volume(≤1.0 cc) local anesthetic, with fluoroscopy or CT scan • No sedation should be given with SNRB, except in extreme cases of anxiety • Document a baseline level of pain • Meaningful improvement in pain=80%, or 5-pt change on VAS • Only one level of surgery will be approved if SNRB is the sole basis for objective diagnosis 		

A request may be appropriate for	AND the diagnosis is supported by these clinical findings			And this has been done (if recommended).
Surgical Procedure & Diagnosis	Subjective	Objective	Imaging	Conservative care
ACDF or TDA Laminotomy Foraminotomy Corpectomy For Radiculopathy - 2 levels	<p>A 2-level surgery may be approved if the following criteria are met:</p> <p>All of the criteria above for single-level fusion (not including SNRB) are present at the primary level, AND</p> <ul style="list-style-type: none"> • The adjacent level has radicular pain correlating with at least moderate foraminal stenosis or lateral recess herniation, OR • EMG changes, muscle weakness or reflex changes that indicate involvement of the adjacent level <p>If the first level has no findings except the response to SNRB, a second level is not allowed.</p> <p>Total disc arthroplasty is contraindicated in the presence of moderate to severe facet arthropathy or measurable instability (>3.5mm) and or > 11° of rotational difference to either adjacent level.</p>			
ACDF Laminotomy Foraminotomy Corpectomy For Radiculopathy-3 or more	<p>All the objective criteria above for single level radiculopathy, which does not include SNRB's, must be met for <i>each</i> level for which surgery is being requested.</p> <p>All requests for 3 or more levels will be automatically reviewed by a physician.</p>			
ACDF Laminotomy Foraminotomy Corpectomy For adjacent segment pathology	<p>There is insufficient evidence in the medical literature to support a causal link between symptomatic adjacent segment pathology and cervical fusion. Therefore treatment for ASP will generally not be accepted, unless there is compelling radiographic evidence that previous surgery has directly compromised, (e.g. hardware displacement) the adjacent segment.</p>			

A request may be appropriate for	AND the diagnosis is supported by these clinical findings			And this has been done (if recommended).
Surgical Procedure & Diagnosis	Subjective	Objective	Imaging	Conservative care
<p>ACDF or TDA Laminectomy ± fusion Corpectomy For Myelopathy, single- level</p>	<p>History of: Hand clumsiness or incoordination, gait disturbance, bowel or bladder dysfunction,</p>	<p>A combination of abnormal lower and upper motor neuron findings in upper extremities,</p> <p style="text-align: center;">AND</p> <p style="text-align: center;">OR</p> <p>Upper motor neuron signs in the lower extremities.</p> <p>Examples:</p> <ul style="list-style-type: none"> • Loss of fine motor control • Weakness • Hand clumsiness • Gait disturbance • Bowel or bladder dysfunction • Increased tone in arms and/or legs • Hyperactive reflexes including Hoffman’s sign and/or clonus 	<p>Myelogram with CT scan OR MRI</p> <p>Abnormal imaging that correlates with subjective and objective findings:</p> <p style="text-align: center;">AND</p> <p>Cord signal change OR compression with loss of circumferential CSF signal OR stenosis (≤8mm AP diameter)</p> <p>In the case of discordant reading between surgeon and radiologist, an independent radiology opinion is needed</p>	<p>Not required if there is evidence of myelopathy</p>
<p>ACDF, laminectomy ±fusion, laminoplasty, corpectomy For Myelopathy, multi-level</p>	<p>If the criteria above, including imaging findings, are met for single- level myelopathy, the levels of surgical intervention will be left to the surgeon’s discretion.</p>			

II. INTRODUCTION

This guideline is intended as a community standard for health care providers who treat injured or ill workers in the Washington workers' compensation system under Title 51 RCW, and as review criteria for the department's utilization review team, to help ensure that diagnosis and treatment of cervical neck conditions are of the highest quality. The emphasis is on accurate diagnosis and curative or rehabilitative treatment (see [WAC 296-20-01002](#) for definitions).

This guideline was developed in 2014 by a subcommittee of the statutory [Industrial Insurance Medical Advisory Committee](#) (IIMAC). Subcommittee members are actively practicing physicians specializing in rehabilitation medicine, occupational medicine, orthopedic surgery, neurology, and pain management. The subcommittee based its recommendations on the weight of the best available clinical and scientific evidence from a systematic review of the literature, and on a consensus of expert opinion when scientific evidence was insufficient.

The emphasis of this guideline is on cases that are clearly work-related and may require surgical treatment. Accurate assessment and treatment are critical to determining work-relatedness and facilitating the worker's return to health and productivity.

III. BACKGROUND AND PREVALENCE

Neck-related pain is common in both the workers' compensation and general populations. Many cases of axial neck pain are temporary and will resolve with time and non-operative treatment (Todd et al.) It can be difficult to distinguish between an acute or chronic condition related to work, and chronic pain and degeneration related to aging.

Cervical degenerative disc disease (DDD) is a common cause of pain and disability, affecting approximately two-thirds of the U.S adult population^[1]. Most symptomatic cases present between the ages of 40 and 60^[2], although many individuals never develop symptoms. MRI studies have documented the presence of DDD in 60% of asymptomatic individuals aged greater than 40 years and 80% of patients over the age of 80^[3,4]. Previous neck injuries, cervical strains, and arthritis increase the risk of developing DDD, which may result in the development of abnormal bony spurs (spondylosis). Less commonly, cervical DDD progression and its sequelae may directly compress parts of the spinal cord (myelopathy), affecting gait and balance.

Treatment options for DDD include conservative and surgical measures. In the general population, the rate of surgery for degenerative disc disease of the cervical spine increased 90% between 1990 and 2000^[5]. In elderly patients in the U.S., rates of cervical fusions rose 206% between 1992 and 2005^[6]. Annual costs for anterior cervical fusions increased 3 fold (\$1.62 billion to \$5.63 billion) between 2000 and 2009^[7].

IV. ESTABLISHING WORK-RELATEDNESS

The etiology of radiculopathies and myelopathies can be multi-factorial or unknown. A cervical condition presenting with a history of radiating arm pain, scapular pain, diminished muscle stretch reflexes, loss of sensation, or motor weakness, may be classified as an occupational injury or occupational disease depending upon the circumstances giving rise to the condition. If there was a single inciting event resulting in objective medical findings, the condition is likely the result of an occupational injury. If there was no single inciting event, the condition may have arisen as the result of an occupational disease. (To be accepted by the department additional legal requirements must be met, see [RCW 51.08.100](#)). The pain and other manifestations of both industrial injuries and occupational diseases generally become evident within 3 months of the inciting event. For this reason, a condition reported for the first time more than 3 months after a patient is first seen by a provider, may not be industrially related. Attribution of such a condition to an industrial event should be based upon careful analysis and thoroughly documented.

A. Cervical conditions as industrial injuries:

Mechanisms of injury to the cervical spine may include: distortion of the neck due to sudden movement of the head, being struck by an object, or a fall from a height ^[8-10]. Examples include motor vehicle crashes, high impact accidents, explosions and gunshots ^[11-13].

An acute injury to the cervical spine should be clinically diagnosable as work-related within 3 months of the injury. For an injury claim to the neck to be accepted beyond 3 months, the attending provider is required to present substantial evidence linking symptoms directly to the initial industrial injury. Claims with insufficient documentation linking clinical symptoms to the initial industrial injury beyond 1 year will generally not be accepted.

B. Cervical conditions as occupational diseases:

Cervical spine conditions may also develop as a natural consequence of aging, resulting in the deterioration of the cervical disc. To establish a diagnosis of an occupational disease, all of the following **are required**:

1. **Exposure:** Workplace activities that contribute to or cause cervical spine conditions, **and**
2. **Outcome:** A diagnosis of a cervical spine condition that meets the diagnostic criteria in this guideline, and
3. **Relationship:** For a cervical condition to be allowed as an occupational disease, the provider must document that, based on generally accepted scientific evidence, the work exposures created a risk of contracting or worsening the condition relative to the risks in everyday life, on a more-probable-than-not basis (***Dennis v. Dept. of Labor and Industries, 1987***). In epidemiological studies, this will usually translate to an odds ratio (OR) ≥ 2 .

More information on filing a claim for an occupational disease, including billing information, can be found in the Attending Provider's Handbook: <http://www.lni.wa.gov/FormPub/Detail.asp?DocID=1669>

V. MAKING THE DIAGNOSIS

A. History and clinical exam:

The classic presentation of cervical radiculopathy includes radiating arm pain, scapular pain, diminished muscle stretch reflexes, loss of sensation, and motor weakness, with or without neck pain. Cervical myelopathy is characterized by loss of motor control, gait disturbances and bowel or bladder dysfunction.

B. Diagnostic Testing--Imaging/Myelogram/EMG's:

Requirements for diagnostic testing and imaging are specified in the criteria table. The basis for the selection of a diagnostic imaging procedure should be based on the information obtained from a thorough clinical exam.

C. Selective Nerve Root Blocks (SNRBs):

Selective nerve root blocks are only considered criteria for surgery when a worker presents with radicular pain, imaging findings, and a history of 6 weeks of conservative care (as in the criteria table), but does not have the objective signs of motor, reflex or EMG changes. Selective nerve root blocks should be used only when:

- The worker has clear sensory symptoms indicative of radiculopathy or nerve root irritation, and
- The worker's symptoms and exam findings are consistent with injury or irritation of the nerve root that is to be blocked; and
- Injury or irritation of the nerve root to be blocked has not been shown to exist by electrodiagnostic, imaging or other studies.

The provider giving the injection has the principal responsibility to document the outcome of the selective nerve root block. The provider should:

- Perform a pre-injection exam, and document the pain intensity using a validated scale.
- Explain to the worker the use and importance of the post-injection pain diary.
- Use low-volume local anesthetic (≤ 1.0 cc) without steroid for the selective nerve root block. Conscious sedation should not be used in the administration of selective nerve root blocks, except in cases of extreme anxiety. If sedation is used, the reason(s) must be documented in the medical record, and the record must be furnished to the department or self-insurer.
- Administer the selective nerve root block using fluoroscopic or CT guidance. An archival image of the injection procedure must be produced, and a copy must be provided to the department or self-insurer.
- Onset (within 1 hr.) of pain relief should be consistent with the anesthetic used; duration generally lasting 2-4 hrs.

- Keep the worker in the office for 15-30 minutes post-injection if possible, and assist with starting the pain diary:
 - Immediately preceding the block, the worker should record the level of pain using a validated scale. Every 15 minutes thereafter, for at least 6 hours following injection, the worker should indicate his or her level of pain. For the remaining waking hours during the 24 hours following the administration of the block, hourly documentation of pain levels is desirable.
 - An example of a pain diary is included in this guideline. Pain must be measured and documented using validated tools such as a visual analog scale or a 10-point scale. See L&I's opioid prescribing guideline (www.opioids.LNI.WA.GOV) for a two-item graded chronic pain scale, which is a valid measure of pain and pain interference with function.
- Document the effect of the block.
 - A positive block is indicated by:
 - An overall 80% improvement in pain, pain reduction by at least 5 points on a 10-point scale or visual analog scale; AND
 - Pain relief that lasts an amount of time consistent with the duration of the anesthetic used.
 - A negative block may be indicated by:
 - No pain relief or less than 5 points on a 10-point scale or visual analog scale, and/or
 - Pain relief that is inconsistent in duration with the usual mechanism of action of the local anesthetic given.
- Ensure that the surgeon and the department or self-insurer receive the above information.

If the block is negative, surgery will not be approved. Only one level of surgery will be approved if the basis of the objective diagnosis is the selective nerve root block.

VI. TREATMENT

A. Conservative Treatment

Conservative management of cervical radicular symptoms may include active physical therapy, osteopathic manipulation, chiropractic manipulation, traction, NSAIDS and steroid injections.

- There is some evidence that an active treatment approach results in better outcomes ^[14, 15]. Physical therapy accompanied by home exercise for 6 weeks has been shown in a randomized trial to substantially reduce neck and arm pain for patients with cervical radiculopathy ^[16].
- Steroid injections may provide short term pain relief for patients with radiculopathy ^[17, 18], although they are not without risks. The injection typically includes both steroid and a long acting anesthetic. See L&I's guideline on spinal injections at <http://www.lni.wa.gov/ClaimsIns/Providers/TreatingPatients/ByCondition/SpinalInjections.asp>

WARNING about epidural steroid injections: On April 23rd 2014, the US FDA put out a warning that the injection of corticosteroids into the epidural space of the spine may result in rare but serious adverse events, including loss of vision, stroke, paralysis and death. (FDA Drug Safety Communications 4-23-2014)

B. Surgical Treatment

The ideal surgical approach for radiculopathy related to herniated disc remains a matter of debate. Various studies have compared the different surgery types and found no significant difference among them. Cervical surgeries can be divided into 2 major approaches: anterior (with or without fusion) and posterior. With the exception of hybrid surgeries, the choice of surgical procedure is left to the discretion of the surgeon.

Anterior cervical decompression alone: Discectomy is a surgical procedure to remove part of a herniated disc to alleviate pressure on the surrounding nerve roots. Discectomy is generally a safe procedure with associated risk such as infection, bleeding, and nerve damage. Studies, albeit dated, comparing discectomy to discectomy plus fusion have found no statistically significant difference between simple discectomy and discectomy followed by fusion in the treatment of cervical radiculopathy ^[19-21].

Posterior Surgeries: Posterior cervical laminotomy/foraminotomy is a highly effective therapeutic procedure for both myelopathy and radiculopathy, as it maintains cervical range of motion, and minimizes adjacent segment degeneration ^[22-24]. Kyphosis and continued persistent neck pain have been concerns with posterior foraminotomies but studies have shown it to be comparable to ACDF's in clinical outcomes ^[25-27].

Anterior Cervical Discectomy with Fusion (ACDF): Anterior cervical surgery has become a standard treatment for cervical disc disease and it is a proven intervention for patients with myelopathy and radiculopathy as it affords the surgeon the ability to restore stabilization ^[28-30]. Various implant and graft devices have been developed for use with ACDF ^[19, 20].

Total Disc Arthroplasty (TDA): Total disc arthroplasty has been proposed as a viable alternative to ACDF. The theoretical basis for cervical arthroplasty is that it maintains motion and may decrease the likelihood of adjacent segment disease and therefore reduce the rate of reoperations ^[31, 32]. Various studies have shown similar outcomes for ACDF and TDA ^[33-35].

Total disc arthroplasty is not indicated for multi-level disease (more than 2 levels). The FDA recently approved a device for 2-level arthroplasty. The Mobi- C cervical disc prosthesis is intended to replace two adjacent cervical discs (from C3-C7). The device is indicated for skeletally mature patients for reconstruction of disc following discectomy at two contiguous levels for radiculopathy or myelopathy. For radiculopathy, patients should have failed 6 weeks of conservative treatment or demonstrate progressive signs and symptoms. Conservative treatment is not required if there is evidence of myelopathy.

Multi-level surgeries: For radiculopathy, a multi-level (2 levels or more) surgery may be approved if all of the criteria for a single level, not including selective nerve root blocks, are present at each level being considered for surgery. Multi-level fusion for myelopathy is more common and may be done if indications are met.

A condition requiring two or more levels of surgery is unlikely to be a work-related injury or disease. All requests for 3 or more levels will be automatically reviewed by a physician.

Hybrid surgeries: Hybrid surgeries combine artificial disc replacements and anterior cervical discectomy with fusion at select vertebral bodies (adjacent or non-adjacent) in a single procedure. There is insufficient evidence in medical literature to permit conclusions on its safety and efficacy. ***The department considers hybrid procedures to be experimental and investigational.*** New evidence will be examined as it becomes available.

Repeat surgeries: Request for repeat surgeries will be reviewed on an individual basis. There must have been documented and substantial improvement in pain and function on a validated instrument after the first surgery before a second surgery will be approved.

Intraoperative monitoring: Somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) are sometimes used in neurological and spinal surgeries. The use of intraoperative neurophysiologic spinal cord monitoring is increasing despite a lack of consensus regarding accuracy, appropriate indications, and overall clinical benefits^[36-41].

The use of intraoperative monitoring for routine decompressive procedures (e.g., discectomy, laminectomy) with or without fusion will not be approved. Intraoperative monitoring may be recommended for treatment of spinal deformities, traumatic dislocations, myelopathy, or posterior cervical instrumentation^[42].

Intraoperative monitoring, with necessity explained, must be requested at the time of surgery request.

Pseudarthrosis (Non Union): Pseudarthrosis exists when there is a complete absence of bridging bone and either hardware failure or measurable instability. Symptomatic pseudarthrosis can be diagnosed based on clinical presentation and diagnostic imaging. For a repeat surgery to be approved, CT SPECT or CT imaging showing non incorporation of bone or flexion and extension radiograph showing interspinous motion greater than or equal to 2 mm.

A contributor to pseudarthrosis is smoking, as nicotine seems to block the ability of osteoblast to form new bone, and is a vasoconstrictor^[43-45]. Other patient- specific metabolic conditions such as diabetes may also contribute to non-union^[46].

Smoking cessation:

Nicotine use is a strong contraindication to spine surgeries. Patients undergoing cervical fusions and repeat fusions for radiculopathy are required to abstain from nicotine for 4 weeks before surgery. Smoking cessation may be covered in some cases; see department policy at <http://www.lni.wa.gov/ClaimsIns/Providers/TreatingPatients/ByCondition/TobaccoCessation.asp>

VII. ADJACENT SEGMENT PATHOLOGY

Adjacent segment degeneration, adjacent segment disease and adjacent segment pathology (ASP) are terms commonly used to describe a degenerative pathology of the spine. The phenomenon of ASP is not fully understood. It has been predicted that more than 25% of all patients would develop ASP during the first 10 years after anterior cervical discectomy and fusion (ACDF) ^[47].

It remains unclear as to whether these conditions are related to altered biomechanics or represent the natural history of the cervical spine. It has been suggested that excessive motion of given segments leads to an increased risk of disc degeneration after fusion. Fusion has been associated with ASP but various studies have failed to show that it is an isolated factor ^[48, 49]. Adjacent segment pathology has been seen after both anterior and posterior surgeries, suggesting other factors may accelerate pathologic changes ^[50, 51].

Adjacent segment pathology has been the driving force for the development of new alternative treatment methods such as total disc arthroplasty (TDA). These options were theoretically designed to be ideal substitutes for ACDF because of their motion preserving benefits ^[30, 52]. However, short term studies comparing ACDF to TDA have failed to show any significant difference in the rate of adjacent segment disease following surgery. ^[35, 53-60].

There is insufficient evidence in the medical literature to support a causal link between symptomatic adjacent segment pathology and cervical fusion. Therefore treatment for ASP will generally not be accepted, unless there is compelling radiographic evidence that previous surgery has directly compromised, (e.g. hardware displacement) the adjacent segment.

VIII. MEASURING FUNCTIONAL IMPROVEMENT

The goal of treatment is to improve pain and function. Providers should measure and document functional improvement throughout conservative and surgical treatment. Levels of pain must be documented when evaluating the results from selective nerve root blocks. Visual analog scales (VAS) or a 10 point scale have been useful for this purpose. The two-item graded chronic pain scale, as recommended in the L&I opioid prescribing guideline, (available at www.opioids.LNI.WA.GOV) is a simple way to document how much pain is interfering with function.

The Neck Disability Index (NDI), SF-36, SF-12, and VAS are tools recommended by the North American Spine Society (NASS) to assess pain and function and to measure outcome of treatment. Other validated scales and instruments may be used to document improvement, or lack thereof.

IX. POST-OPERATIVE PHASE AND RETURN TO WORK:

It is important for the attending provider and the surgeon to focus on preoperative planning for postop recovery, reactivation, and return to work activities. During the immediate postop period, (6 weeks) the surgeon should help direct these activities. It is the responsibility of the attending provider to determine if the patient can be allowed to perform temporary duties with or without restrictions.

Pain relief will likely be a concern during recovery. Pain can be effectively managed with passive and active therapies, non-opioid pain relievers, or short-term opioids. For information and tools on how to use opioids in the perioperative period, see L&I's opioid prescribing guideline at www.opioids.LNI.WA.GOV.

Evidence shows that work accommodation combined with conservative care during the early recovery period can help prevent disability. Jobsite modifications are dependent on the nature of the patient's work tasks, their injury, and their response to rehabilitation. Typically, factors such as lifting, pulling, and repetitive overhead work require modifications in position, force, repetitions, and/or duration. Those workers returning to jobs with heavy lifting or prolonged overhead work may need additional weeks of rehabilitation. To find resources on job modifications and return to work programs, visit the LNI.wa.gov and search for the [Stay at Work](#) program.

X. REFERENCES

1. Todd, A.G., *Cervical spine: degenerative conditions*. Curr Rev Musculoskelet Med, 2011. 4(4): p. 168-74.
2. Kelly, J.C., P.J. Groarke, J.S. Butler, A.R. Poynton, and J.M. O'Byrne, *The natural history and clinical syndromes of degenerative cervical spondylosis*. Adv Orthop, 2012. 2012: p. 393642.
3. Matsumoto, M., Y. Fujimura, N. Suzuki, Y. Nishi, M. Nakamura, Y. Yabe, and H. Shiga, *MRI of cervical intervertebral discs in asymptomatic subjects*. J Bone Joint Surg Br, 1998. 80(1): p. 19-24.
4. Lehto, I.J., M.O. Terti, M.E. Komu, H.E. Paajanen, J. Tuominen, and M.J. Kormanio, *Age-related MRI changes at 0.1 T in cervical discs in asymptomatic subjects*. Neuroradiology, 1994. 36(1): p. 49-53.
5. Patil, P.G., D.A. Turner, and R. Pietrobon, *National trends in surgical procedures for degenerative cervical spine disease: 1990-2000*. Neurosurgery, 2005. 57(4): p. 753-8; discussion 753-8.
6. Wang, M.C., W. Kreuter, C.E. Wolfla, D.J. Maiman, and R.A. Deyo, *Trends and variations in cervical spine surgery in the United States: Medicare beneficiaries, 1992 to 2005*. Spine (Phila Pa 1976), 2009. 34(9): p. 955-61; discussion 962-3.
7. Alosch, H., D. Li, L.H. Riley, 3rd, and R.L. Skolasky, *Health Care Burden of Anterior Cervical Spine Surgery: National Trends in Hospital Charges and Length of Stay, 2000 to 2009*. J Spinal Disord Tech, 2013.
8. Buitenhuis, J., P.J. de Jong, J.P. Jaspers, and J.W. Groothoff, *Work disability after whiplash: a prospective cohort study*. Spine (Phila Pa 1976), 2009. 34(3): p. 262-7.
9. Funk, J.R., J.M. Cormier, and S.J. Manoogian, *Comparison of risk factors for cervical spine, head, serious, and fatal injury in rollover crashes*. Accid Anal Prev, 2012. 45: p. 67-74.
10. Fredo, H.L., S.A. Rizvi, B. Lied, P. Ronning, and E. Helseth, *The epidemiology of traumatic cervical spine fractures: a prospective population study from Norway*. Scand J Trauma Resusc Emerg Med, 2012. 20: p. 85.
11. Nelson, D.W., M.J. Martin, N.D. Martin, and A. Beekley, *Evaluation of the risk of noncontiguous fractures of the spine in blunt trauma*. J Trauma Acute Care Surg, 2013. 75(1): p. 135-9.
12. Schoenfeld, A.J., J.C. Dunn, J.O. Bader, and P.J. Belmont, Jr., *The nature and extent of war injuries sustained by combat specialty personnel killed and wounded in Afghanistan and Iraq, 2003-2011*. J Trauma Acute Care Surg, 2013. 75(2): p. 287-91.
13. Schoenfeld, A.J., R.L. Newcomb, M.P. Pallis, A.W. Cleveland, 3rd, J.A. Serrano, J.O. Bader, B.R. Waterman, and P.J. Belmont, Jr., *Characterization of spinal injuries sustained by American service members killed in Iraq and Afghanistan: a study of 2,089 instances of spine trauma*. J Trauma Acute Care Surg, 2013. 74(4): p. 1112-8.
14. Jette, D.U. and A.M. Jette, *Physical therapy and health outcomes in patients with spinal impairments*. Phys Ther, 1996. 76(9): p. 930-41; discussion 942-5.
15. Saal, J.S., J.A. Saal, and E.F. Yurth, *Nonoperative management of herniated cervical intervertebral disc with radiculopathy*. Spine (Phila Pa 1976), 1996. 21(16): p. 1877-83.
16. Kuijper, B., J.T. Tans, A. Beelen, F. Nollet, and M. de Visser, *Cervical collar or physiotherapy versus wait and see policy for recent onset cervical radiculopathy: randomised trial*. BMJ, 2009. 339: p. b3883.
17. Anderberg, L., M. Annertz, L. Persson, L. Brandt, and H. Saveland, *Transforaminal steroid injections for the treatment of cervical radiculopathy: a prospective and randomised study*. Eur Spine J, 2007. 16(3): p. 321-8.

18. Kolstad, F., G. Leivseth, and O.P. Nygaard, *Transforaminal steroid injections in the treatment of cervical radiculopathy. A prospective outcome study.* Acta Neurochir (Wien), 2005. 147(10): p. 1065-70; discussion 1070.
19. Hauerberg, J., M. Kosteljanetz, T. Boge-Rasmussen, K. Dons, P. Gideon, J.B. Springborg, and A. Wagner, *Anterior cervical discectomy with or without fusion with ray titanium cage: a prospective randomized clinical study.* Spine (Phila Pa 1976), 2008. 33(5): p. 458-64.
20. Xie, J.C. and R.J. Hurlbert, *Discectomy versus discectomy with fusion versus discectomy with fusion and instrumentation: a prospective randomized study.* Neurosurgery, 2007. 61(1): p. 107-16; discussion 116-7.
21. Savolainen, S., J. Rinne, and J. Hernesniemi, *A prospective randomized study of anterior single-level cervical disc operations with long-term follow-up: surgical fusion is unnecessary.* Neurosurgery, 1998. 43(1): p. 51-5.
22. Jagannathan, J., J.H. Sherman, T. Szabo, C.I. Shaffrey, and J.A. Jane, *The posterior cervical foraminotomy in the treatment of cervical disc/osteophyte disease: a single-surgeon experience with a minimum of 5 years' clinical and radiographic follow-up.* J Neurosurg Spine, 2009. 10(4): p. 347-56.
23. Fehlings, M.G. and B. Arvin, *Surgical management of cervical degenerative disease: the evidence related to indications, impact, and outcome.* J Neurosurg Spine, 2009. 11(2): p. 97-100.
24. Clarke, M.J., R.D. Ecker, W.E. Krauss, R.L. McClelland, and M.B. Dekutoski, *Same-segment and adjacent-segment disease following posterior cervical foraminotomy.* J Neurosurg Spine, 2007. 6(1): p. 5-9.
25. Lawrence, B.D., W.B. Jacobs, D.C. Norvell, J.T. Hermsmeyer, J.R. Chapman, and D.S. Brodke, *Anterior versus posterior approach for treatment of cervical spondylotic myelopathy: a systematic review.* Spine (Phila Pa 1976), 2013. 38(22 Suppl 1): p. S173-82.
26. Fehlings, M.G., S. Barry, B. Kopjar, S. Tim Yoon, P. Arnold, E.M. Massicotte, A. Vaccaro, D.S. Brodke, C. Shaffrey, J.S. Smith, E. Woodard, R.J. Banco, J. Chapman, M. Janssen, C. Bono, R. Sasso, M. Dekutoski, and Z.L. Gokaslan, *Anterior vs Posterior Surgical Approaches to Treat Cervical Spondylotic Myelopathy: Outcomes of the Prospective Multicenter AOSpine North America CSM Study in 264 Patients.* Spine (Phila Pa 1976), 2013.
27. Liu, X., S. Min, H. Zhang, Z. Zhou, H. Wang, and A. Jin, *Anterior corpectomy versus posterior laminoplasty for multilevel cervical myelopathy: a systematic review and meta-analysis.* Eur Spine J, 2013.
28. Gao, Y., M. Liu, T. Li, F. Huang, T. Tang, and Z. Xiang, *A meta-analysis comparing the results of cervical disc arthroplasty with anterior cervical discectomy and fusion (ACDF) for the treatment of symptomatic cervical disc disease.* J Bone Joint Surg Am, 2013. 95(6): p. 555-61.
29. Jawahar, A., D.A. Cavanaugh, E.J. Kerr, 3rd, E.M. Birdsong, and P.D. Nunley, *Total disc arthroplasty does not affect the incidence of adjacent segment degeneration in cervical spine: results of 93 patients in three prospective randomized clinical trials.* Spine J, 2010. 10(12): p. 1043-8.
30. Coric, D., P.K. Kim, J.D. Clemente, M.O. Boltes, M. Nussbaum, and S. James, *Prospective randomized study of cervical arthroplasty and anterior cervical discectomy and fusion with long-term follow-up: results in 74 patients from a single site.* J Neurosurg Spine, 2013. 18(1): p. 36-42.
31. Blumenthal, S.L., D.D. Ohnmeiss, R.D. Guyer, and J.E. Zigler, *Reoperations in cervical total disc replacement compared with anterior cervical fusion: results compiled from multiple prospective food and drug administration investigational device exemption trials conducted at a single site.* Spine (Phila Pa 1976), 2013. 38(14): p. 1177-82.

32. Heller, J.G., R.C. Sasso, S.M. Papadopoulos, P.A. Anderson, R.G. Fessler, R.J. Hacker, D. Coric, J.C. Cauthen, and D.K. Riew, *Comparison of BRYAN cervical disc arthroplasty with anterior cervical decompression and fusion: clinical and radiographic results of a randomized, controlled, clinical trial*. Spine (Phila Pa 1976), 2009. 34(2): p. 101-7.
33. Mummaneni, P.V., J.K. Burkus, R.W. Haid, V.C. Traynelis, and T.A. Zdeblick, *Clinical and radiographic analysis of cervical disc arthroplasty compared with allograft fusion: a randomized controlled clinical trial*. J Neurosurg Spine, 2007. 6(3): p. 198-209.
34. Zhang, X., C. Chen, Y. Zhang, Z. Wang, B. Wang, W. Yan, M. Li, W. Yuan, and Y. Wang, *Randomized, controlled, multicenter, clinical trial comparing BRYAN cervical disc arthroplasty with anterior cervical decompression and fusion in China*. Spine (Phila Pa 1976), 2012. 37(6): p. 433-8.
35. Sasso, R.C., P.A. Anderson, K.D. Riew, and J.G. Heller, *Results of cervical arthroplasty compared with anterior discectomy and fusion: four-year clinical outcomes in a prospective, randomized controlled trial*. J Bone Joint Surg Am, 2011. 93(18): p. 1684-92.
36. Taunt, C.J., Jr., K.S. Sidhu, and S.A. Andrew, *Somatosensory evoked potential monitoring during anterior cervical discectomy and fusion*. Spine (Phila Pa 1976), 2005. 30(17): p. 1970-2.
37. Khan, M.H., P.N. Smith, J.R. Balzer, D. Crammond, W.C. Welch, P. Gerszten, R.J. Scلابassi, J.D. Kang, and W.F. Donaldson, *Intraoperative somatosensory evoked potential monitoring during cervical spine corpectomy surgery: experience with 508 cases*. Spine (Phila Pa 1976), 2006. 31(4): p. E105-13.
38. Peeling, L., S. Hentschel, R. Fox, H. Hall, and D.R. Fournay, *Intraoperative spinal cord and nerve root monitoring: a survey of Canadian spine surgeons*. Can J Surg, 2010. 53(5): p. 324-8.
39. Schwartz, D.M., A.K. Sestokas, J.P. Dormans, A.R. Vaccaro, A.S. Hilibrand, J.M. Flynn, P.M. Li, S.A. Shah, W. Welch, D.S. Drummond, and T.J. Albert, *Transcranial electric motor evoked potential monitoring during spine surgery: is it safe?* Spine (Phila Pa 1976), 2011. 36(13): p. 1046-9.
40. Hilibrand, A.S., D.M. Schwartz, V. Sethuraman, A.R. Vaccaro, and T.J. Albert, *Comparison of transcranial electric motor and somatosensory evoked potential monitoring during cervical spine surgery*. J Bone Joint Surg Am, 2004. 86-A(6): p. 1248-53.
41. Kim, D.H., J. Zaremski, B. Kwon, L. Jenis, E. Woodard, R. Bode, and R.J. Banco, *Risk factors for false positive transcranial motor evoked potential monitoring alerts during surgical treatment of cervical myelopathy*. Spine (Phila Pa 1976), 2007. 32(26): p. 3041-6.
42. Virginia Mason Medical Center and Group Health Cooperative, *Guideline: Intraoperative neurophysiological monitoring (IONM)*. 2013.
43. Hilibrand, A.S., M.A. Fye, S.E. Emery, M.A. Palumbo, and H.H. Bohlman, *Impact of smoking on the outcome of anterior cervical arthrodesis with interbody or strut-grafting*. J Bone Joint Surg Am, 2001. 83-A(5): p. 668-73.
44. Goldberg, E.J., K. Singh, U. Van, R. Garretson, and H.S. An, *Comparing outcomes of anterior cervical discectomy and fusion in workman's versus non-workman's compensation population*. Spine J, 2002. 2(6): p. 408-14.
45. Mok, J.M., J.M. Cloyd, D.S. Bradford, S.S. Hu, V. Deviren, J.A. Smith, B. Tay, and S.H. Berven, *Reoperation after primary fusion for adult spinal deformity: rate, reason, and timing*. Spine (Phila Pa 1976), 2009. 34(8): p. 832-9.
46. Kim, H.J., S.H. Moon, H.S. Kim, E.S. Moon, H.J. Chun, M. Jung, and H.M. Lee, *Diabetes and smoking as prognostic factors after cervical laminoplasty*. J Bone Joint Surg Br, 2008. 90(11): p. 1468-72.

47. Hilibrand, A.S., G.D. Carlson, M.A. Palumbo, P.K. Jones, and H.H. Bohlman, *Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis*. J Bone Joint Surg Am, 1999. 81(4): p. 519-28.
48. Lee, M.J., J.R. Dettori, C.J. Standaert, E.D. Brodt, and J.R. Chapman, *The natural history of degeneration of the lumbar and cervical spines: a systematic review*. Spine (Phila Pa 1976), 2012. 37(22 Suppl): p. S18-30.
49. Wilder, F.V., L. Fahlman, and R. Donnelly, *Radiographic cervical spine osteoarthritis progression rates: a longitudinal assessment*. Rheumatol Int, 2011. 31(1): p. 45-8.
50. Acikbas, S.C., C. Ermol, M. Akyuz, and R. Tuncer, *Assessment of adjacent segment degeneration in and between patients treated with anterior or posterior cervical simple discectomy*. Turk Neurosurg, 2010. 20(3): p. 334-40.
51. Lundine, K.M., G. Davis, M. Rogers, M. Staples, and G. Quan, *Prevalence of adjacent segment disc degeneration in patients undergoing anterior cervical discectomy and fusion based on pre-operative MRI findings*. J Clin Neurosci, 2014. 21(1): p. 82-5.
52. Coric, D., J. Cassis, J.D. Carew, and M.O. Boltz, *Prospective study of cervical arthroplasty in 98 patients involved in 1 of 3 separate investigational device exemption studies from a single investigational site with a minimum 2-year follow-up. Clinical article*. J Neurosurg Spine, 2010. 13(6): p. 715-21.
53. Maldonado, C.V., R.D. Paz, and C.B. Martin, *Adjacent-level degeneration after cervical disc arthroplasty versus fusion*. Eur Spine J, 2011. 20 Suppl 3: p. 403-7.
54. Nunley, P.D., A. Jawahar, E.J. Kerr, 3rd, C.J. Gordon, D.A. Cavanaugh, E.M. Birdsong, M. Stocks, and G. Danielson, *Factors affecting the incidence of symptomatic adjacent-level disease in cervical spine after total disc arthroplasty: 2- to 4-year follow-up of 3 prospective randomized trials*. Spine (Phila Pa 1976), 2012. 37(6): p. 445-51.
55. Song, J.S., B.W. Choi, and K.J. Song, *Risk factors for the development of adjacent segment disease following anterior cervical arthrodesis for degenerative cervical disease: Comparison between fusion methods*. J Clin Neurosci, 2013.
56. Verma, K., S.D. Gandhi, M. Maltenfort, T.J. Albert, A.S. Hilibrand, A.R. Vaccaro, and K.E. Radcliff, *Rate of adjacent segment disease in cervical disc arthroplasty versus single-level fusion: meta-analysis of prospective studies*. Spine (Phila Pa 1976), 2013. 38(26): p. 2253-7.
57. Coric, D., P.D. Nunley, R.D. Guyer, D. Musante, C.N. Carmody, C.R. Gordon, C. Laurysen, D.D. Ohnmeiss, and M.O. Boltz, *Prospective, randomized, multicenter study of cervical arthroplasty: 269 patients from the Kineflex|C artificial disc investigational device exemption study with a minimum 2-year follow-up: clinical article*. J Neurosurg Spine, 2011. 15(4): p. 348-58.
58. Burkus, J.K., R.W. Haid, V.C. Traynelis, and P.V. Mummaneni, *Long-term clinical and radiographic outcomes of cervical disc replacement with the Prestige disc: results from a prospective randomized controlled clinical trial*. J Neurosurg Spine, 2010. 13(3): p. 308-18.
59. Nabhan, A., W.I. Steudel, D. Pape, and B. Ishak, *Segmental kinematics and adjacent level degeneration following disc replacement versus fusion: RCT with three years of follow-up*. J Long Term Eff Med Implants, 2007. 17(3): p. 229-36.
60. Murrey, D., M. Janssen, R. Delamarter, J. Goldstein, J. Zigler, B. Tay, and B. Darden, *Results of the prospective, randomized, controlled multicenter Food and Drug Administration investigational device exemption study of the ProDisc-C total disc replacement versus anterior discectomy and fusion for the treatment of 1-level symptomatic cervical disc disease*. Spine J, 2009. 9(4): p. 275-86.

Acknowledgements

This guideline was developed in 2014 by Labor and Industries' Industrial Insurance Medical Advisory Committee (IIMAC) and its subcommittee on cervical spine conditions. Acknowledgement and gratitude go to all subcommittee members, clinical experts, and consultants who contributed to this important guideline:

IIMAC Committee Members

Bob Lang MD, Chair
Andrew Friedman MD
Kirk Harmon MD
Chris Howe MD
Karen Nilson MD

Subcommittee Clinical Experts

Farrokh Farrokhi MD
Mike Lee MD
JC Leveque MD

Clinical consultants to the Committee

Hugh Allen MD
James Babington MD
Michele Curatolo MD
Ken Reger MD

Consultation provided by:

Shari Fowler-Koorn RN, Qualis Health
Terrell Kjerulf MD, Qualis Health
Ken O'Bara MD, Qualis Health

Department staff who helped develop and prepare this guideline include:

Gary M. Franklin MD MPH, Medical Director
Lee Glass MD, Associate Medical Director
Hal Stockbridge MD MPH, Associate Medical Director
Nicholas K Reul MD, MPH
Teresa Cooper MN, MPH, Occupational Nurse Consultant
Bintu Marong MS, Epidemiologist