

Anterior Cervical Spine Surgery for Degenerative Disease: A Review

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Abstract

Anterior cervical spine surgery is an established surgical intervention for cervical degenerative disease and high success rate with excellent long-term outcomes have been reported. However, indications of surgical procedures for certain conditions are still controversial and severe complications to cause neurological dysfunction or deaths may occur. This review is focused mainly on five widely performed procedures by anterior approach for cervical degenerative disease; anterior cervical discectomy, anterior cervical discectomy and fusion, anterior cervical corpectomy and fusion, anterior cervical foraminotomy, and arthroplasty. Indications, procedures, outcomes, and complications of these surgeries are discussed.

Key words: anterior cervical spine surgery, degenerative disease, indication, outcome, complication

Introduction

Anterior cervical spine surgery has been widely performed as a standard procedure for cervical spondylosis, disc hernia, ossified posterior longitudinal ligament (OPLL), spinal and spinal cord tumors, and vascular diseases. This surgery has substantial advantages to visualize and treat the lesions directly, since the disc hernias, spondylotic osteophytic spurs, and OPLL exist anterior to the spinal cord and spinal nerves. And damages to the muscles are minimal by anterior cervical spine surgery, because muscles do not attach to the middle anterior surface of the cervical vertebral body. On the other hand, there are disadvantages of the anterior cervical spine surgery. A majority of this procedure sacrifices the disc function after a fusion procedure. And, there are vulnerable important organs such as esophagus, trachea, and recurrent laryngeal nerve (RLN), and major complications may occur. This review is focused on the anterior cervical spine surgery as a treatment for cervical degenerative disease, and indication, procedures, outcomes, and complications are discussed. The articles were selected based on the following criteria: (1) written in English or Japanese,

(2) studies about the effects or complications of anterior cervical spine surgery, and (3) guidelines or retrospective studies or a prospective studies or case reports.

General Indications and Procedures of Anterior Cervical Spine Surgery

Indication of the anterior cervical spine surgery for cervical degenerative disease is still controversial. But, in general, this surgery should be considered for the anterior lesions which compress spinal cord or spinal nerve, such as osteophytic spurs or disc hernias. Among these lesions, the cases in which the extent of the lesions confined to 3-disc levels or necessity for fusion procedure or vertebral body removal are supposed to be good candidates for the anterior cervical spine surgery. On the other hand, posterior cervical spine surgery is indicated for posterior lesions which compress spinal cord or nerve roots, and when the lesions are extended beyond 3-disc levels or OPLL with extensive dural ossification. In this review, standard procedures of the anterior cervical spine surgery; anterior cervical discectomy, anterior cervical discectomy with fusion (ACDF), anterior cervical corpectomy with fusion (ACCF), anterior cervical foraminotomy, and arthroplasty are discussed.

Comprehensive Reviews and Guideline of Anterior Cervical Spine Surgery for Cervical Spondylotic Radiculopathy and Myelopathy by Non-profit Organization and Medical Societies

I. Systematic review articles of the cervical spine surgery by the Cochrane Collaboration

Nikolaidis et al. included two randomized studies of total 149 patients with radiculopathy or myelopathy due to cervical spondylotic diseases in their systematic review.¹⁾ They found low quality evidence that surgery provided pain relief faster than physiotherapy or hard collar immobilization in cervical radiculopathy, but there was no or little evidence in the long term. Low quality evidence showed that patients with mild myelopathy felt subjectively better shortly after surgery than non-surgical treatment, but there was little or no difference in the long term.

Jacobs et al. reviewed single or double-level anterior interbody fusion techniques for cervical degenerative disc disease.²⁾ They collected 33 studies (2,267 patients) and compared different surgery techniques; anterior cervical discectomy, ACDF using autograft or allograft or a cage. There was no evidence that one technique was better than another for clinically significant pain relief for patients with chronic cervical degenerative disc disease. Moderate quality evidence showed little or no difference in Odom's criteria between ACDF with iliac autograft and that with a metal cage. They found moderate quality evidence that the use of bone graft was more effective than discectomy alone in achieving fusion, and low quality evidence that ACDF with iliac crest autograft was more effective in achieving fusion than a cage, while the cage was more effective in preventing complications.

Boselie et al. published a review article to assess the effects of arthroplasty versus fusion for radiculopathy or myelopathy, or both due to single-level cervical disc disease.³⁾ They included 9 studies with 2,400 participants. There was high-quality evidence that segmental mobility was larger in arthroplasty group at 1–2 years at the treated level, but no difference was detected in the necessity of secondary surgery at adjacent levels in this period. Low quality evidence showed a small significant difference in alleviation of arm pain at 1–2 years in favor of arthroplasty. Moderate quality evidence showed a small difference in neck-related functional status and neurological outcome in favor of arthroplasty. However, this review indicated the possible publication bias,

because smaller studies showed larger difference for the outcome.

II. Systematic review by the Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons/Congress of Neurological Surgeons (AANS/CNS)

The evidence was classified into three levels.⁴⁾ Briefly, Class I evidence evolved from well-designed randomized controlled trials (RCTs), Class II evidence arose from RCTs with design problems or from well-designed cohort studies, and Class III evidence arose from case series or poorly designed cohort studies.

For the treatment of cervical spondylotic myelopathy, widely utilized techniques including ACDF, ACCF, laminoplasty, and laminectomy with fusion improved functional outcome (Class III).⁵⁾ ACDF and ACCF exhibited similar results in multilevel spine decompression for lesions at the disc level (Class III). Without anterior plating, ACCF provided a higher fusion rate and a higher graft failure rate than multilevel ACDF (Class III). Laminectomy was associated with late deterioration compared to other types of anterior and posterior surgeries (Class III). Patients with mild spondylotic myelopathy (modified Japanese Orthopedic Association scale score > 12) responded to surgical decompression or nonoperative therapy (Class II).⁶⁾ More severe myelopathic patients responded to surgical decompression and the effects of the surgery were maintained for 5–15 years (Class III).

Regarding the indication of the anterior cervical spine surgery for cervical spondylotic radiculopathy,⁷⁾ anterior cervical discectomy and ACDF resulted in more rapid relief (within 3–4 months) of arm/neck pain, weakness, and/or sensory loss compared to physical therapy and cervical collar immobilization and the effects of these surgery lasted over 12 months (Class I). Anterior cervical foraminotomy also exhibited improvement in clinical function in a majority of the patients, but the evidence was weak and recurrent symptoms were seen in 30% (Class III). There was another review to identify the best techniques for anterior cervical nerve root decompression.⁸⁾ Anterior cervical discectomy and ACDF were equivalent treatment strategies for 1-level disease regarding functional outcome (Class II). Anterior cervical plating improved arm pain better than ACDF in the treatment of 2-level disease (Class II). For 1-level disease, plating might reduce the risk of pseudo-arthrodesis and graft problems (Class III) but did not improve clinical outcome (Class II). Cervical arthroplasty was recommended as an alternative to ACDF in selected patients with neck and arm pain (Class II).

III. The North American Spine Society (NASS) evidence-based clinical guideline for the diagnosis and treatment of cervical radiculopathy from degenerative disorders⁹⁾

In this guideline, categories of recommendations are classified into five levels; level A, B, C, D, and I. Level A and B are the generally recommended categories.

Surgical treatment is suggested for rapid relief of symptoms of cervical radiculopathy from degenerative disorders when compared with medical or interventional treatment (grade B). For single-level cervical radiculopathy, anterior cervical discectomy and ACDF are suggested as comparable treatment strategies, producing similar clinical outcomes (grade B) and the addition of an interbody graft for fusion is suggested to improve sagittal alignment after the anterior cervical discectomy (grade B). Both ACDF with or without a plate are recommended as comparable treatment strategies (grade B), but a plate improves sagittal alignment (grade B). Either ACDF or posterior foraminotomy are recommended for the treatment of single-level degenerative cervical radiculopathy secondary to foraminal soft disc herniation (grade B). ACDF and total disc arthroplasty are suggested as comparable treatments with similar successful short-term outcomes for single-level degenerative cervical radiculopathy (grade B). Surgery is an optional treatment for this condition with long-term favorable outcomes (grade C).

Surgical Procedures

I. Indication of anterior cervical discectomy, ACDF, ACCF, and anterior cervical foraminotomy

Among the widely performed surgical procedures of the anterior cervical spine surgery, ACDF and ACCF are generally accepted surgeries for cervical spondylotic myelopathy and radiculopathy as described above.¹⁻⁸⁾ For ACDF, the use of metal cages may reduce complications related to iliac bone harvesting. Anterior plating is reported to improve fusion rate, sagittal alignment, and functional outcomes and reduce graft problems.^{5,8)} However, a majority of the studies with anterior plating was performed with autograft or allograft. Since high fusion rate and low complication rate of ACDF were shown with metal cages,¹⁰⁻¹²⁾ anterior plating should be considered when using bone grafts. ACCF may improve the fusion rate, but increase the risk of graft failure. Arthroplasty may improve functional outcomes, but it is too early to determine its efficacy. In conclusion, ACDF with metal cages and ACDF using bone grafts with anterior plating show better outcomes and fewer complications than the anterior cervical discectomy and anterior cervical foraminotomy, but

ACCF can also be indicated for the lesions that cannot be treated by intervertebral approach.

II. The approach side of anterior cervical spine surgery

The approach side of the anterior cervical spine surgery does not change the outcomes and complication rates including RLN injury.¹³⁾ However, information should be acquired before the decision of approach side. It is reasonable to avoid surgery on the side of the previous one-side anterior cervical surgery. Patients with hoarseness should be examined by laryngoscope for vocal cord palsy, and if the paresis is detected, surgery should be performed on the same side to prevent catastrophic complication of bilateral vocal cord paralysis.¹⁴⁾ Pre-existing one-side carotid artery stenosis rationalizes the surgery on the other side, since retraction on carotid artery may cause lethal stroke.¹⁵⁾

III. Intraoperative monitoring

Intraoperative electrophysiological monitoring under total intravenous anesthesia is recommended for cervical spine surgery to prevent neurological deficits due to cervical spine positioning and intraoperative manipulation of the spinal cord and nerves.¹⁶⁾ Among the electrophysiological monitoring procedure, transcranial electrical stimulation motor evoked potential (MEP), sensory evoked potential (SEP), and spontaneous electromyography are widely performed. MEP shows 100% sensitivity for postoperative neurological deficits in many reports, but the specificity is reported to be lower than SEP in some reports.^{16,17)} Evidence from systematic reviews by Fehlings et al. showed that multimodality intraoperative neuromonitoring was sensitive and also specific for detecting intraoperative neurologic injury during spine surgery. And it is strongly recommended for surgery where the spinal cord or nerve roots are deemed to be at risk.¹⁸⁾

Complications and Treatment

There are vulnerable important organs, such as trachea, esophagus, carotid artery, RLN, and sympathetic nerve trunk anterior to the cervical spine. The complications which require intraoperative management or cause major morbidity/mortality are listed as follows:

1. Dural tear and cerebrospinal fluid (CSF) leakage
Incidence of dural tear during the anterior cervical spine surgery is 1% or less in many reports.¹⁹⁾ If subcutaneous CSF leak develops, it can cause not only poor wound healing or infection, but also neck mass and dysphagia.²⁰⁾ When dural injury occurs intraoperatively, there are several procedures to prevent

postoperative CSF leakage.²¹⁾ If the tear is small, dura can be closed with non-absorbable suture or non-penetrating vascular closure staples. When a large dural defect is observed, synthetic dural substitute or autologous fascia can be patched. The use of absorbable sheet and fibrin glue substantially reduces subclinical epidural CSF leak and cutaneous leakage.²¹⁾ For the anterior cervical spine surgery, there is occasionally not enough working space to apply sutures, staples, or dural patch, and in these cases, fibrin glue and absorbable sheet can be just placed on the dura.

2. Esophageal injury

Esophageal perforation is uncommon but life-threatening complication occurs with an incidence of 0.02–3.4%.^{22–25)} Perforation occurs at upper esophagus or pyriform sinus of pharyngoesophageal junction. It is rarely recognized intraoperatively, but diagnosed within 10 days of surgery in many cases, however, in some cases symptoms develop several months/years after surgery. Anterior plating especially carries a risk for delayed esophageal perforation,²²⁾ but removal of the plate is not usually scheduled. As a consequence of esophageal injury, high mortality rate (4–50%) is reported due to mediastinitis, sepsis, or meningitis, and therefore, early diagnosis and treatment are important.^{23–25)} If clear fluid leakage is observed intraoperatively, injury site should be immediately investigated, and if found the tear should be repaired by an esophagus surgeon. Postoperative sore throat, dysphagia, and mis-swallowing are important local signs, and fever, tachycardia, and pneumoderma suggest the possibility for esophageal injury.^{23–25)} In such suspected cases, prompt swallowing contrast imaging and/or endoscopy should be performed.

3. Vascular injury and stroke

Vertebral artery injury by the anterior cervical spine surgery is uncommon with an incidence of 0.1–0.5%, but often results in severe neurological deficit.^{26–28)} Most of the injuries occurred during ACCF, but rarely during ACDF.²⁷⁾ Vertebral artery is located 1–2 mm laterally from uncovertebral joints and excessive lateral bone removal by the Kerrison bone punch or high-speed drill may result in laceration of vertebral artery. When removing a part of Luschka joints, care should be taken not to expose dural root sleeve more than 5 mm.^{29,30)} It is also noteworthy that the risk is greater more at the cephalad vertebra during lateral extension of the central decompression procedures, because inter-Luschka distance increases from C3 to C7.^{29,31)} Furthermore, for the cases that require uncovertebral joints resection, preoperative contrast-enhanced three-dimensional computed tomography (3D-CT) is mandatory, since there is 3% incidence of anomalous,

tortuous vertebral artery.³²⁾ Once bleeding occurs intraoperatively, compression of the bleeding point using gelform or cottonoids should be tried for temporal hemostasis,²⁷⁾ and threads or vascular closure staples can be used for repair of arterial wall.³³⁾ When these trials fail, ligation of vertebral artery can be considered, but it may lead to cerebellar/brain stem infarction and the mortality rate is as high as 12%.³⁴⁾

Carotid artery injury by the anterior cervical spine surgery is extremely rare.³⁵⁾ It is not well known that traction of normal carotid artery by retractor causes significant reduction in blood flow,³⁶⁾ and indeed, prolonged retraction of the normal common carotid artery can induce lethal stroke.¹⁵⁾ As described above, preoperative evaluation of the carotid artery is needed for the patients with a history of previous stroke, and approach side should be discussed and long retraction should be avoided.

4. Airway obstruction

Airway obstruction after the anterior cervical spine surgery is caused by retropharyngeal hematoma or edema of soft tissues and the incidence is 1–6%.^{37–39)} It occurs minutes to 10 days after surgery, but most frequently, 24–48 hours. Recently, local retropharyngeal steroid administration is reported to reduce prevertebral soft tissue swelling,³⁹⁾ but careful hemostasis and avoidance of prolonged retraction are essential to prevent this catastrophic event. Multi-level surgery (> 2 disc-level), surgery cephalad to C4, bleeding more than 300 ml and long operation time (> 90 min or > 5 hours) are risk factors for postoperative airway obstruction.^{39,40)} In case of the airway obstruction due to hematoma, early detection and hematoma evacuation are the keys to save patients.

5. Hoarseness and vocal code paralysis

Hoarseness after the anterior cervical spine surgery has been reported to be a consequence of RLN palsy.⁴¹⁾ Right RLN leaves the vagus nerve and loops under subclavian artery, while the left RLN leaves vagus nerve at the mediastinum and passes over the aorta. After branching from vagus nerve, right nerve does not go into the tracheoesophageal groove until it approaches the cricothyroid joint, whereas left RLN ascends within the tracheoesophageal groove. Right RLN was thought to be easily injured by right side approach of the anterior cervical spine surgery, because it might cross the operative field.⁴²⁾ However, the incidence of postoperative hoarseness does not differ by the side of approach. The overall incidence of RLN palsy had been reported to be 2–3%,^{13,41)} but recent prospective study showed the incidence of hoarseness and subclinical laryngoscopic vocal code paralysis was 8.3%, 15.9% at 3–7 days, and 2.5%,

10.8% at 3 months after surgery, respectively.⁴³⁾ Initial and persistent RLN palsy occurred much more often than anticipated. As a cause of RLN palsy, compression of the RLN within the endolarynx was suggested in some studies.⁴⁴⁾ Endotracheal tube cuff pressure monitoring and release after retractor placement may prevent injury to the RLN during anterior cervical spine surgery.

6. Dysphagia

Dysphagia is often observed after the anterior cervical spine surgery with an incidence of 2–60%.^{45,46)} The incidence has been lower in the reports by surgeons (neurosurgeons and orthopedic surgeons) and higher in those by otolaryngologists. But, recent cohort study by orthopedic surgeons revealed that dysphagia was observed in 54% of patients at 1 year and 14% at 2 years after the anterior cervical spine surgery.⁴⁶⁾ Risk factors were female gender, prolonged operative time, revision surgeries, multilevel surgeries, and the use of bone morphogenetic protein.^{46,47)} The effect of anterior plating on the occurrence of dysphagia is still controversial,^{45,46)} but the removal of anterior plating improved symptoms in 87% of the patient with persistent dysphagia in the previous article.⁴⁸⁾ It is reasonable to consider surgery to remove anterior plates for the patient with severe dysphagia.

7. C5 palsy

Postoperative C5 palsy is estimated to occur in 0–30% of the patients after the anterior cervical spine surgery, but the etiology is still unclear.^{49–51)} There is higher incidence after ACCF than ACDF, especially when surgery involves C3/4 and C4/5 segments.^{50,51)} In a review article, the overall incidence of C5 palsy after the cervical spine surgery for compression myelopathy was 4.6%, and when C5 palsy is 3–4 grade in manual muscle test (MMT), 96.4% of the patients recovered fully, whereas only 71% of the patients with initial MMT 0–2 grade recovered to the useful level.⁵¹⁾ Injury to the nerve root during surgery, nerve root traction due to the shift of cervical spinal cord after decompression, and spinal cord ischemia and reperfusion injury have been proposed as mechanisms of postoperative C5 palsy, but pathogenesis has not been clarified. There is no effective method for prevention, but the surgeons must know the risk factor and prognosis of this complication.

8. Adjacent segment disease

Spondylotic changes are known to occur at adjacent discs following anterior cervical fusion surgery.^{12,52,53)} In the recent systematic review of the articles with an average follow-up of 107 months (ranged 24–296 months) after ACDF, the average incidence

of asymptomatic adjacent segment degeneration is 47.33% with a range from 16% to 96% and the that for symptomatic adjacent segment disease was 11.99% with a range from 1.8% to 36%.⁵²⁾ Revision surgery due to adjacent segment disease was performed in 2–15% in the long-term follow-up studies.^{12,53,54)} Cervical disc arthroplasty has been expected to preserve the range of motion of cervical segments and reduce the incidence of adjacent segment degeneration, however, the effect is still controversial. Recent meta-analysis of prospective studies compared arthroplasty and single level fusion, but the rate of adjacent-level surgery at 2 years to 5 years of follow-up was 6.9% after ACDF and 5.1% after arthroplasty, with no statistical difference.⁵⁵⁾ In conclusion, there is no effective surgical procedure to reduce the incidence of the adjacent segment disease.

Informed Consent

Possible life-threatening events and the important complications which require intraoperative treatment or affects patients' quality of life are described above. Scoliosis Research Society Morbidity and Mortality Committee collected the data of more than 100,000 spine surgeries and reported complication rates.⁵⁶⁾ There is 0.3% infection, 0.3% implant failure, 0.14% pulmonary embolism and deep venous thrombosis, and 0.06% deaths after ACDF. Besides the complications listed above, these rates must also be informed preoperatively to the patients.

Conflicts of Interest Disclosure

There are no conflicts of interest. The author registered online self-reported COI disclosure statement forms through website for Japan Neurosurgical Society members.

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