The Resident's Guide to Spine Surgery

Joseph R. O'Brien
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Preface

Spine surgery in 2019 is more advanced than ever. As a multidisciplinary field, it draws from the expertise of orthopaedic surgeons and neurosurgeons. Additionally, the advances in minimally invasive techniques have added a layer of complexity.

For residents in either specialty, it can be a daunting task to learn all of the procedures in a short period of time. This book has been assembled by a group of experts with a long tradition of educating residents. The overarching goal has been to create a concise guide to each procedure and make it "learnable". For both orthopaedic and neurological resident surgeons, this book will be a guide to acquire the requisite skills in spine surgery.

Bethesda, MD, USA — Joseph R. O'Brien, MD, MPH

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Chapter 1
Anterior Cervical Discectomy and Fusion

Crystal Adams, Fadi Sweiss, Michelle Feinberg, and Jonathan H. Sherman

Indications and Patient Selection

The anterior cervical discectomy and fusion for single-level disc disease was first described by Smith, Cloward, and Robinson in 1958 and the use of anterior cervical plates was introduced in the 1960s [8]. Since that time, the anterior cervical discectomy and fusion (ACDF) procedure has become a mainstay in spinal surgery and its indications have expanded. Overall, the primary goal of the procedure is to relieve mechanical pressure on the spinal cord and/or spinal nerve roots associated with the patients' presenting symptomatology. Surgical intervention becomes necessary when patients' symptoms are refractory to nonsurgical treatment. Typical symptoms can include radicular pain, weakness, numbness, as well as difficulty walking. Some patients may also experience bowel or bladder incontinence [18].

There are several key indications for the use of the ACDF procedure and appropriate patient selection is of the utmost importance to ensure the best patient outcomes. In particular, it is helpful in patients presenting with either cervical radiculopathy or myelopathy secondary to disc herniation, anterior osteophyte complexes, or bony spurs which cause spinal canal narrowing and spinal cord compression or nerve root impingement [5]. Additionally, this procedure may be helpful in patients presenting with spondylitic radiculopathy. It may be successfully utilized in patients presenting with both single-level and multilevel cervical disease [5].

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As with any procedure, there are some contraindications for utilizing an ACDF procedure. Patients whose cervical pathology is mostly posterior are not appropriate candidates for this procedure as a posterior approach would more adequately address the likely cause of their symptoms. Additionally, as will be discussed later, there are some risks associated with an anterior approach to the cervical spine such as impaired vocal cord function which some patients may be unwilling to risk. Finally, there are patients who may be poor surgical candidates in general due to significant medical comorbidities.

There are several key advantages to the ACDF. The primary advantage is that it allows the surgeon to address anterior pathology under direct vision. Second, the procedure involves a complete discectomy which promotes an overall better rate of fusion. An additional advantage is that it avoids the need for patients to be placed in prone position, particularly in elderly patients who may have multiple cardiopulmonary comorbidities.

Alternatives to ACDF include anterior cervical discectomy without fusion, cervical total disc replacement, cervical laminoplasty, posterior cervical foraminotomy, and cervical laminectomy with or without fusion.

Preoperative Planning

Patients should have appropriate preoperative imaging and exams prior to the procedure. A preoperative cervical spine MRI provides the best assessment of the spinal canal and more specifically the spinal cord. Patients may also have a cervical CT scan and/or flexion-extension x-rays to assess for evidence of any motion abnormalities suggesting instability. Patients who are unable to undergo an MRI due to presence of metal implants may have a CT myelogram. A thorough understanding of the patients' vertebral arterial anatomy is imperative to decrease the risk of inadvertent vertebral artery injury during the case. Preoperative imaging should also be used to assess anticipated dimensions of the plate and screws to be used. Given the associated risk of vocal cord dysfunction postoperatively, patients who have had a prior anterior cervical approach surgery may need to undergo a preoperative ENT evaluation with laryngoscopy to assess for preoperative vocal cord function. In one study, they found that 17.3% of patients had abnormal findings on laryngoscopic exam which affected decisions regarding approach for revision ACDF [9]. Patients with significant cardiopulmonary comorbidities should obtain necessary medical clearance prior to undergoing surgery. In addition, knowledge of patients' medical comorbidities and social history is important for assessing risk of fusion failure as well as for appropriate intraoperative and postoperative management.

Anesthetic Considerations and Preoperative Medications

In patients with cervical myelopathy or evidence of cervical instability, awake fiberoptic intubation may be performed to help minimize the potential for inadvertent neurologic trauma. The use of SSEPs during surgery requires that the anesthetic

cocktail utilized be one that preserves these signals. This is typically one that utilizes a moderate dose narcotic-based regimen supplemented by an inhalation agent [12]. Preoperative antibiotics are typically given by anesthesia [7]. Some surgeons may also opt to give preoperative DVT prophylaxis with subcutaneous heparin. Additionally, preoperative steroids may be given to the patient to help decrease the risk of edema [13]. Of note, during the procedure the endotracheal cuff should be intermittently deflated to decrease risk of injury to the recurrent laryngeal nerve.

Neuromonitoring

Intraoperative neuromonitoring is an adjunct when performing an ACDF, the use of which is depending on surgeon's preference. Typically, EMG, SSEPs, and MEPs are utilized during the procedure. Preoperative baselines are performed prior to the start of the procedure, and surgeons are alerted to any signal changes during the procedure [12].

Positioning

The patient is placed in supine position with the head of the bed towards the anesthesia team. The bed can be raised in reverse Trendelenburg to facilitate venous drainage. The arms are tucked at the side. A radiolucent bed is used to facilitate intraoperative fluoroscopy. The neck is then placed in slight extension [7]. A shoulder roll is placed under the scapulae. Some surgeons place this roll vertically between the scapulae while other surgeons orient the roll horizontally. In addition to a shoulder roll, some surgeons utilize Gardner-Wells tongs with 5 to 10 pounds of traction to assist with visualization and to assist with keeping the neck in neutral rotation as well as to provide additional cervical lordosis. The shoulders are then taped down to allow for better visualization of the lower cervical spine. As an alternative to taping the shoulders, soft straps can be placed around the wrists and pulled down. Several landmarks can be used to denote certain cervical levels. The angle of the mandible can be used to approximate the C2 vertebral body. The hyoid bone is located at the C2-C3 interspace [16]. The thyroid cartilage is typically at the C4-C5 disc interspace. The cricoid cartilage typically overlies the C6 level [3, 16]. Prior to incision, a metal object, such as a towel clamp, is used in association with fluoroscopy to identify the surgical levels to ensure the positioning allows for adequate exposure. Adjustments can be made based on these preoperative fluoroscopic images.

Approach

The anterior cervical spine may be approached from either the left or the right side. The side a surgeon chooses for the approach is often dictated by surgeon preference. However, there are certain circumstances where other factors must be taken into

account. For example, if a patient has had a prior anterior cervical surgery, the surgeon will often use the prior incision. In patients who have vocal cord paralysis, the cervical spine is approached from the side with the paralysis. Additionally, surgical anatomy varies to some degree between right- and left-sided approaches. In particular, the recurrent laryngeal nerve on the right has a more variable course and tends to lie more anterolateral thus putting it in a more vulnerable position for injury during approach particularly at lower cervical levels. The thoracic duct is visible on the left side at the C7-T1 level and must be protected during a left-sided approach at this level.

In most cases, a transverse incision is used along a natural skin fold. This spans from the midline to the anterior border of the sternocleidomastoid. However, for access to greater than 3 levels, a longitudinal incision along the medial sternocleidomastoid muscle may be necessary [7]. A longitudinal incision may also be necessary in extremely obese patients.

After the skin incision is performed, the platysma is sharply incised and elevated at both ends of the incision. This can be done using either Metzenbaum scissors or bovie cautery. Blunt dissection is then employed below the platysma muscle. The degree of necessary subplatysmal dissection is dictated by the number of levels to be addressed. In continuing with dissection, the cervical fascia is then opened anterior to the sternocleidomastoid muscle and dissection is proceeded along the medial border of the sternocleidomastoid muscle. The plane between the sternocleidomastoid muscle and the strap muscles is identified and both blunt and sharp dissection is used to exploit this plane [3, 10]. Special attention must be paid to the location of several key structures during this dissection to avoid inadvertent injury. In particular, the superior and inferior thyroid arteries extend from carotid towards midline through the pretrachial fascia at the C3–4 and C6–7 levels respectively. In continuing with the dissection, the carotid sheath is retracted laterally and the trachea and esophagus are retracted medially with handheld retractors. The prevertebral fascia is then excised in the midline and the vertebral bodies and disc spaces become palpable. It is important that the midline be maintained during the entire procedure. The appropriate level is identified and a spinal needle is inserted and the level is confirmed with lateral fluoroscopy. The longus colli muscles are then stripped laterally. This can be done with or without bovie cautery. A self-retaining retractor system is then utilized to retract the longus colli muscles. One should keep in mind that the cervical sympathetic plexus lies along the longus colli muscle and are at risk for injury with significant dissection along the longus colli muscles. The anterior longitudinal ligament is then dissected off the anterior vertebral bodies [3, 10].

Depending on surgeon preference, a microscope may or may not be used for the decompression portion of the procedure. While some surgeons argue that that microscope allows for enhanced visualization for the entire surgical team other surgeons prefer to use only surgical magnifying loupes. In either case, the next step in the procedure is the discectomy. At this point, a pin retractor system is utilized to create disc space distraction. A small window is made in the disc space with an 11-blade. The superficial disc material is removed using a combination of curettes and pituitary rongeurs. A Leksell rongeur may also be used to remove anterior disc

osteophytes prior to the discectomy. For the deeper portion, a high-speed carbide or diamond burr drill can be used to remove all bony disc osteophyte material while preserving the posterior longitudinal ligament [13, 18]. The key in this portion of the procedure is to try to remove all bony disc material without injuring the vertebral artery. Typically, an adequate decompression is considered to have been obtained if the posterior osteophytes have been addressed, the neural foramina have been decompressed, and a 3 mm area of bone remains on each side to protect the vertebral artery. In addition to removing the bony disc material, the entire posterior longitudinal ligament is removed in a chevron fashion across the entire interspace utilizing Kerrison rongeurs. Right-angled nerve hooks are used to explore the neural foramen on each side to ensure adequate decompression. Kerrison rongeurs can be utilized to provide further decompression if necessary.

The next portion of the procedure is the fusion. The bony endplates are drilled to promote fusion. An interbody spacer sizer is used to measure the size of the disc space. An appropriate-sized structural bone graft or cage packed with autograft or allograft is then inserted into the disc space using a mallet [3, 11]. Intraoperative fluoroscopy is then used to confirm adequate placement.

A titanium cervical plate of appropriate length to span the fusion levels is chosen. Preoperative imaging can be used to measure anticipated plate length. The plate is temporarily fixed with pins and appropriate position verified by fluoroscopy prior to placement of screws. Screw holes are then made using a manual drill. The upper screws are angled rostrally and the lower screws are angled caudally at each level to be divergent to the disc space. Screws are typically between 12 and 16 mm. The screws are then tightened and locked in place. The final position is then verified by fluoroscopy.

After final confirmation of position, the self-retaining retractor system is removed. The superficial and deeper portions of the incision are then inspected and adequate hemostasis is obtained using bipolar cautery. The wound is irrigated with bacitracin irrigation. In multilevel ACFDs, a drain may be left in place. For closure, the platysma is re-approximated using 3–0 vicryl interrupted sutures. The skin is then approximated with buried 3–0 vicryl interrupted sutures and dermabond is placed over the skin incision. Alternatively, a running subcuticular 4–0 monocryl can be used to close the skin incision [3].

Postoperative Course

Patients are typically admitted to the surgical floor overnight for monitoring. Immediate postoperative AP and lateral x-rays are often obtained. However, some surgeons prefer to obtain standing AP and lateral cervical spine x-rays prior to discharge. Depending on bone quality, surgeons may opt to have some patients wear a cervical collar until follow-up in clinic [13]. Patients are usually encouraged to ambulate early once they have recovered from anesthesia. Patients are typically evaluated by physical therapy and occupational therapy on postoperative day 1.

Some patients may require speech therapy evaluation due to dysphagia or swallowing difficulty due to manipulation during surgery. In cases where a drain was left in place, it can usually be removed on postoperative day 1 if output is relatively low. Many patients are able to be discharged home on postoperative day 1. Some patients may require a slightly prolonged hospital stay.

Of note, there are some institutions which have started to perform single and two level ACDFs on an outpatient basis at ambulatory surgery centers. A retrospective study conducted by Adamson et al. compared 1000 consecutive patients undergoing ACDFs performed at an ambulatory surgery center with 484 consecutive patients undergoing ACDFs performed at the associated hospital. Their study showed similar complication rates in both groups with serious complications such a postoperative hematoma or vascular injury were last than 0.5% in both groups. The overall conclusion was that ACDFs can be performed safely in the ambulatory surgery center setting. However, they emphasized that not all patients are appropriate for surgery in this setting which underscores the need to have a good understanding of each patient's underlying medical comorbidities prior to surgery [1].

Potential Complications

There are several well-defined potentially serious complications which can occur with the procedure. A cerebrospinal fluid leak may occur and, if possible, should be repaired primarily. Dural substitutes or fibrin glue may also be used. Patients should be kept upright after the procedure in the case of a cervical spinal fluid leak. A lumbar drain may need to be placed if the leak does not resolve [3]. There is also risk of vertebral artery injury during the procedure particularly if the exposure is too lateral. In one study looking at 992 ACDF procedures, vertebral artery injury occurred in 0.3% of the cases during foraminal decompression. This point reinforces the need to have a good understanding of the patient's vertebral artery course on preoperative imaging. Should a vertebral artery injury occur, it is important to try and obtain sufficient hemostasis as quickly as possible with hemostatic packing such as gelfoam [15]. Better exposure of the vertebral artery may be required to identify the site of bleeding [3]. Should adequate hemostasis not be able to be obtained, the involved vertebral artery segment may need to be IR intervention [15]. Another potential complication is hematoma formation requiring evacuation. For this reason, patients are watched closely for evidence of airway compromise in the postoperative period.

Other potential complications include recurrent laryngeal nerve injury, tracheal or esophageal injury, graft or screw migration, pseudoarthrosis, and future adjacent segment disease [3, 4, 6]. Rates of adjacent segment disease after ACDF vary greatly in the literature from 25% to 92% [2]. In a systematic review performed by Lawrence et al., they estimated the risk of symptomatic adjacent segment disease as anywhere between 1.6% and 4.2% per year [14]. In the immediate postoperative period, some patients experience dysphagia and/or difficulty swallowing requiring speech therapy evaluation and diet adjustment. In some cases, patients may require

temporary alternative means of nutrition such as a dobhoff tube or PEG tube in more severe cases. In a retrospective study performed by Wang et al., they found that increased operative time was a factor that significantly increased immediate postoperative dysphagia. Additionally, smoking and diabetes were the patient factors that most significantly affected rate of recovery from postoperative dysphagia [17]. Some patients also experience hoarseness in the immediate postoperative period which typically improves over several days. In some cases, patients may benefit from a short course of postoperative steroids to decrease perioperative edema. In a double-blinded randomized controlled trial performed by Jeyamohan et al., patients received either preoperative IV dexamethasone or placebo and then received postoperative IV dexamethasone every 6 h for the first 24 h after surgery or placebo. Their results showed that patients receiving the steroids had significantly lower rates of dysphagia and trend in decreased number of airway issues and need for intubation trended towards significance in the steroids group. Of note, their study did reveal that rate of fusion was significantly lower in the steroids group at 6 months but that there was no significant difference in fusion rate between groups at 12 months' follow-up [13].

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Chapter 2
Cervical Corpectomy

Gregory Callanan, Ra' Kerry Rahman, and Kris Radcliff

Introduction

Anterior cervical corpectomy and fusion (ACCF) is a surgical technique utilized to treat patients when a more generous decompression is required than capable with discectomy alone. By far, the most common condition treated with this technique is cervical spondylotic myelopathy (CSM). It is also utilized to remove vertebrae that have been damaged or otherwise deformed from trauma or neoplasms of the cervical spine. It is performed by removal of the affected vertebral body and associated intervertebral discs to allow for decompression of the cervical cord. A strut graft or cage construct is then placed into the void to stabilize the anterior column. Anterior plating can be used to provide stability and support during the fusion process. Segmental anterior plating is especially recommended when performing multilevel corpectomies due to the high incidence of early instrument failure [8, 17]. Furthermore, posterior instrumentation may be necessary to support multilevel corpectomies [18]. This chapter will discuss the application of ACCF in the clinical setting as well as technical aspects of the procedure.

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Indications for Cervical Corpectomy

The presence of retrovertebral disease is the primary indicator for use of the corpectomy procedure. ACCF has been shown to be an effective procedure for decompressing the anterior spinal cord. Multilevel discectomies should be performed when feasible over corpectomy procedures. When retrovertebral disease is present and multilevel surgery is required, a hybrid discectomy/corpectomy procedure is a viable option [15, 16]. Cervical corpectomy has several advantages/disadvantages that a surgeon should consider when contemplating this technique for patients. Corpectomy is generally favored over multilevel anterior discectomy in cases of long segment ossification of the posterior longitudinal ligament (OPLL), traumatic disruption of the vertebral body, osteomyelitis, and neoplasms [3]. Essentially, all of these conditions require either expanded decompression in order to attain the desired clinical result or removal of the vertebral body to accomplish the clinical goal. This removal is necessary to provide space for appropriate anterior column support and/or is part of a treatment plan for proper resection. Corpectomy has the ability to provide a more complete decompression, especially when there is significant stenosis behind the vertebral body. Corpectomy also has the advantage of improved visualization, fewer bone-graft interfaces to heal and a greater surface area to help facilitate fusion [8]. Hence, the theoretical risk of pseudarthrosis is less with ACCF compared to multilevel ACDF. Fraser et al. performed a meta-analysis investigating the fusion rates between ACDF with plating and ACCF. The authors reported no significant difference between ACDF with plating and ACCF when investigating two level disease; for three level disease however, the authors reported that ACCF was associated with higher fusion rates than ACDF [5].

The disadvantages include greater approach morbidity per level, more technically demanding than discectomy only procedure, greater risk of vertebral artery injury, more bleeding, more exposure of the spinal cord with resultant risk of iatrogenic injury, higher implant and graft complication profile, subsidence, and risk of suboptimal postoperative sagittal alignment [13, 14].

Surgical Approach

The patient is positioned supine on the operating table after induction and intubation. A longitudinal bump is placed between the patient scapulae with a small pillow beneath the patient's head in order to place the cervical spine into slight extension. Extreme caution must be taken when positioning the patient cervical spine and intubation to avoid neurological deterioration secondary to hyperextension of the stenotic canal in those patients with significant myelopathy. The patient's arms are tucked at the side with shoulders taped caudally to help with proper visualization during exposure and lateral radiographs. Care should be taken to prevent excessive traction of the patient shoulders that may result in a brachial plexus injury. Pay

careful attention to upper extremity neuromonitoring baseline potentials obtained before taping for comparison. It is helpful to take a fluoroscopic image before prepping in order to refine positioning. A decision should be made in regard to need for Mayfield tongs or Gardner-Wells (GW) tongs. The author prefers 15–20lbs of Gardner-Wells traction in addition to the use of vertebral distraction pins to obtain desired postop lordosis. This requires GW tong placement slightly anterior to the cervical axis of rotation.

The anterior cervical spine can be accessed from the right or left side depending on surgeon preference. A transverse incision is utilized for procedures involving one to two levels. For procedures involving three or more disc levels, a longitudinal or oblique incision may be used. The vertebral segments involved determine the location of the incision. There are palpable landmarks of the anterior neck that will help guide the surgeon to the appropriate location for the incision. The angle of the mandible demarcates the C2–3 interspace. The hyoid bone typically lies anterior to C3 level. The superior portion of the thyroid cartilage marks C4–5 interspace. The location of C6 can be determined via palpation of the cricoid cartilage or by palpation of the carotid tubercle which projects anteriorly from the transverse process. Intraoperative fluoroscopy can also be utilized to localize the operative level.

Once the incision has been made through the skin and subcutaneous tissue, the platysma is divided in line with the skin. Any superficial veins encountered must be protected or ligated if they cross the planes of dissection. The vein pattern encountered is most often a single vertical vein. However, infrequently a Y-shaped bifurcation is encountered and at other times two bifurcations may be seen. Be prepared to ligate the veins if bleeding is uncontrollable. Dissection is continued through the superficial layers of the investing deep cervical fascia between the sternocleidomastoid and the medial visceral muscle column. Next, the carotid sheath must be palpated. Blunt dissection is performed through the middle layer of deep cervical fascia between the esophagus and carotid sheath. The author prefers to use a Peanut sponge to sweep the fascia laterally while protecting the carotid sheath. This provides medial lateral dimension for the work necessary. The prevertebral fascia will then be visualized anterior to the vertebral column. This fascia is subsequently incised and dissected off the vertebral bodies. The medial borders of the longus colli muscles are now identified off of the midline. The midline can be marked at this point to reference for decompression and graft alignment later in the procedure. The operative level is marked and lateral fluoroscopy confirms the level.

Following the confirmation of the operative level, the longus colli is elevated using mono or bipolar cautery. The author prefers bipolar cautery as the bleeding of the dorsal or undersurface of the longus colli is better controlled with bipolar. It also helps the surgeon delineate when the mid-body bleeding is the result of a bone tributary versus muscle vein. Proceeding with the dissection, the longus is elevated from the level of the mid-vertebral body above and below the body of interest. Care must be taken to avoid dissection on the ventral surface of the longus colli muscles that may result in injury of the sympathetic chain causing Horner syndrome. Next, place retractors under the longus colli bilaterally.