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RESEARCH ARTICLE

ANTERIOR CERVICAL DISCECTOMY AND FUSION (ACDF): A REVIEW OF SURGICAL APPROACHES FOR CERVICAL SPINE DISORDERS

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Abstract

Anterior cervical discectomy and fusion (ACDF) is one of the most widely performed surgical procedures for managing cervical spine pathologies,including cervical radiculopathy,myelopathy, and traumatic or degenerative disc disease.This review aims to provide a comprehensi ve overview of the historical evolution,surgical techniques,graft materia ls,instrumentation options, clinical outcomes, and complication profiles of ACDF, with emphasis on the comparative analysis of alternative anterior and posterior approaches. Literature from pubmed, Scopus, and Google Scholar between 1950 and 2025 was reviewed. Evidence sugge sts that ACDF provides high rates of symptom resolution and fusion su ccess, though risk of complications such as dysphagia, adjacent segmen t disease, and pseudarthrosis persists. Advancements in minimally inva sive techniques and biomaterials continue to refine surgical outcomes.

Introduction: -

Cervical spine disorders are a significant cause of chronic pain, neurological deficits, and disability worldwide. They include degenerative disc disease, cervical spondylosis, herniated discs, traumatic instability, tumors, and inflammatory lesions.

Cervical radiculopathy affects about 83 per 100,000 people annually, while cervical myelopathy is the most common cause of spinal cord dysfunction in older adults.[1] These conditions have substantial socioeconomic consequences due to long-term treatment and reduced productivity. Anterior cervical discectomy and fusion (ACDF) is considered the gold standard surgical treatment for radiculopathy and myelopathy when conservative measures fail. The anterior approach enables direct decompression of neural structures and stabilization via interbody fusion, relieving symptoms and preventing further neurological decline. [2]

ACDF was first described in the late 1950s by Smith and Robinson, and independently by Cloward. Smith and Robinson used an oblique anterior approach with an iliac crest autograft, while Cloward employed a dowel graft technique for stability. Both achieved excellent results, laying the foundation for modern cervical spine surgery. Over the decades, ACDF has evolved with significant refinements in technique, graft selection, and fixation methods. [3] The shift from iliac crest autografts to PEEK, titanium, and carbon fiber cages reduced donor site morbidity while maintaining fusion rates. The introduction of anterior plating in the 1980s improved stability, fusion success, and multi-level procedure outcomes. [4]

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Recent advancements include minimally invasive and endoscopic ACDF, aiming to reduce tissue trauma, perioperative complications, and postoperative dysphagia. Despite its success, ACDF has recognized risks, including dysphagia, recurrent laryngeal nerve palsy, pseudarthrosis, and adjacent segment degeneration—especially in multi-level surgeries. [5] Growing interest in motion-preserving alternatives, such as cervical disc arthroplasty, has prompted reevaluation of ACDF's long-term biomechanical effects. This review examines current evidence on ACDF, comparing traditional and minimally invasive techniques, discussing graft and fixation options, evaluating complications, and offering guidance for optimal patient selection and outcomes. [6]

Historical Background:

Anterior cervical discectomy and fusion (ACDF) originated in the mid-20th century as a transformative approach to cervical spine surgery. In 1955**,** Smith and Robinson introduced an anterior approach for cervical decompression, utilizing a horseshoe-shaped autologous iliac crest graft to restore disc height and maintain stability. Their method provided direct access to the pathological disc and addressed both central and foraminal compression in a single exposure. Almost simultaneously, Ralph Cloward described **a** dowel graft technique, inserting a cylindrical autograft harvested from the iliac crest into the prepared disc space. His emphasis on direct visualization and thorough discremoval improved decompression quality and spinal alignment. [7]

Subsequent refinements included the Bailey-Badgley slot graft, which offered enhanced load-sharing, and the Simmons-Bhalla keystone graft**,** designed to resist graft migration and subsidence. These innovations sought to improve fusion stability and reduce complications. A major milestone came in the **1980s** with the introduction of anterior cervical plating**.** Rigid internal fixation provided immediate stability, improved fusion rates, reduced graft-related complications, and enabled earlier patient mobilization—particularly important in multilevel procedures. Modern ACDF techniques integrate these foundational principles with advanced biomaterials, cage systems, and minimally invasive methods, reflecting over six decades of continuous refinement aimed at optimizing patient outcomes. [8]

Indications for ACDF:

Anterior cervical discectomy and fusion (ACDF) is primarily indicated for cervical spine pathologies that cause neural compression and segmental instability, particularly when conservative management has failed or when there is progressive neurological decline. The main clinical scenarios include:

1. **Degenerative Disc Disease with Radiculopathy or Myelopathy**
   Chronic degeneration of the cervical intervertebral discs can lead to loss of disc height, osteophyte formation, and hypertrophy of the uncovertebral and facet joints. These changes may compress nerve roots (radiculopathy) or the spinal cord (myelopathy), resulting in pain, sensory loss, motor weakness, and gait disturbances. ACDF is indicated when symptoms are persistent and significantly impact function despite adequate non-operative therapy.
2. **Cervical Spondylotic Myelopathy (CSM):**
   CSM is the most common cause of spinal cord dysfunction in adults over the age of 55. It results from progressive degenerative narrowing of the cervical spinal canal, often at multiple levels. ACDF is particularly suited for cases with ventral cord compression, as it allows for direct removal of osteophytes and disc material while restoring cervical lordosis. [9]

3. **Cervical Disc Herniation Refractory to Non-Surgical Treatment:**
   Acute or subacute disc herniations that cause severe radicular pain, weakness, or myelopathy and do not respond to analgesics, physiotherapy, or epidural steroid injections may require ACDF. The anterior approach provides direct access to the herniated material, enabling complete decompression of the affected nerve root and spinal cord.

4. **Traumatic Injuries with Instability:** High-energy trauma, such as motor vehicle accidents or falls, can cause fractures, ligamentous injury, ordislocation in the cervical spine. In cases where there is anterior column compromise or disc disruption with instability, ACDF can achieve decompression, realignment, and stabilization in a single-stage procedure. [10]

5. **Neoplastic Lesions Requiring Decompression and Stabilization:** Primary or metastatic tumors involving the cervical vertebral bodies or intervertebral discs can cause neural compression and spinal instability. ACDF enables removal of the pathological tissue from an anterior approach, followed by reconstruction and stabilization to maintain spinal integrity.

6. **Infective Pathologies After Debridement:**

Infections such as cervical spondylodiscitis or vertebral osteomyelitis may necessitate surgical debridement when there is neurological compromise, instability, or failure of medical therapy. ACDF allows removal of infected tissue, decompression of neural elements, and stabilization with appropriate grafting, often combined with postoperative antimicrobial therapy. [11]

Surgical Approaches and Techniques:

Traditional Open ACDF:

The traditional open anterior cervical discectomy and fusion (ACDF) remains the gold standard for treating symptomatic cervical degenerative disc disease, radiculopathy, and myelopathy. The procedure begins with a transverse or oblique skin incision along a natural skin crease in the anterior neck. Blunt dissection is performed through the platysma and along anatomical planes to reach the prevertebral space**,** taking care to protect the carotid sheath laterally and the trachea–esophagus medially. Under direct visualization, the affected intervertebral disc is removed, osteophytes are excised, and the endplates are prepared to optimize graft incorporation. Interbody fusion is achieved using autograft, allograft, or synthetic cages, often supplemented with anterior cervical plating to enhance stability, promote fusion, and reduce the risk of graft dislodgement. This approach allows excellent visualization of the surgical field and precise decompression of neural structures. [12]

Minimally Invasive and Endoscopic ACDF:

Minimally invasive (MI) and endoscopic ACDF techniques have been developed to minimize surgical morbidity while maintaining the efficacy of decompression and fusion. These approaches use smaller skin incisions and tubular or expandable retractors**,** often combined with endoscopic visualization, to reduce soft tissue trauma, postoperative neck pain, and blood loss. Advantages include shorter hospital stays, faster return to work, and improved cosmetic outcomes. However, they require specialized instruments, high-definition optics, andadvanced technical skills**,** leading to a steeper learning curve. Furthermore, the reduced exposure may limit their applicability in cases with severe deformity, extensive osteophyte formation, or multi-level disease. [13]

Multilevel ACDF:

Multilevel ACDF—typically involving two or more contiguous levels—is indicated in patients with multi-segmentcervical spondylosis, myelopathy, or trauma where decompression at multiple sites is required. While it can provide excellent neurological recovery, it carries higher complication rates compared to single-level procedures. These include increased dysphagia, higher risk of pseudarthrosis due to the greater number of fusion interfaces, and a greater likelihood of adjacent segment degeneration (ASD**)** because of altered cervical biomechanics. Surgical planning often involves careful graft selection, consideration of supplemental posterior fixation in high-risk cases, and meticulous attention to alignment to minimize long-term complications. Despite these risks, successful multilevel fusion can yield substantial symptom relief and functional improvement, especially when combined with meticulous postoperative rehabilitation. [14]

Graft Materials and Instrumentation:

Autograft (Iliac Crest):

Autologous iliac crest bone graft has historically been considered the gold standard for ACDF due to its osteogenic, osteoinductive, and osteoconductive properties, leading to consistently high fusion rates exceeding 95% in single-level procedures. The structural integrity of the tricortical graft helps maintain disc height and cervical alignment. However, harvesting autograft introduces donor site morbidity, which may include persistent pain, infection**,** hematoma, sensory disturbances, or gait difficulties**.** This drawback has driven the search for alternatives that avoid a secondary surgical site. [15]

Allograft:
Cadaveric allograft bone eliminates the need for graft harvesting, thereby avoiding donor site pain and shortening operative time. It is readily available in various shapes and sizes, and pre-shaped allografts facilitate surgical handling. However, fusion rates with allografts tend to be slower due to the absence of living osteogenic cells and the need for creeping substitution. While modern sterilization and preservation techniques have reduced the risk of disease transmission, they may also compromise mechanical strength and biological activity. Allografts are often supplemented with anterior plating to enhance stability during the prolonged incorporation phase. [16]

Interbody Cages (PEEK, Titanium):
Polyetheretherketone (PEEK) cagesandtitanium cages have gained popularity as graft substitutes in ACDF. These devices maintain disc height and cervical lordosis**,** reducing the risk of postoperative segmental collapse.

- PEEK cages are radiolucent, allowing clear postoperative imaging to assess fusion, and have an elastic modulus similar to bone, which reduces stress shielding.
- Titanium cages provide excellent structural strength and are often coated with porous or hydroxyapatite layers to enhance osseointegration.
  Both cage types can be filled with autograft, allograft chips, or synthetic bone substitutes, functioning as fusion conduits while preserving intervertebral spacing. [17]

Anterior Cervical Plates:
Anterior cervical plating systems are commonly used to provide rigid segmental fixation**,** particularly in multilevel ACDF or in patients at high risk of graft migration and pseudarthrosis. Plates help maintain sagittal alignment, resist flexion–extension forces, and enhance the likelihood of successful fusion. Modern low-profile and dynamic plate designs aim to reduce the risk of adjacent level ossification and postoperative dysphagia. Their use is especially beneficial in complex reconstructions or when immediate postoperative stability is critical for early mobilization. [18]

Clinical Outcomes:
Several prospective and retrospective studies have shown that anterior cervical discectomy and fusion (ACDF) results in outstanding clinical results in suitably chosen patients. In most series, over 90% of patients report considerable relief from radicular pain, enhancement in sensory deficits, and restoration of motor function shortly after surgery. These advancements are usually maintained over the long term, resulting in significant improvements in functional status, quality of life, and reintegration into the workforce.

Radiographic findings show fusion rates above 95% for single-level ACDF when contemporary fixation methods, including anterior cervical plating and structural interbody grafts, are used. Effective fusion is closely linked to symptom relief, spinal stability, and lower rates of reoperation. In multilevel ACDF, fusion rates stay elevated but could be somewhat reduced, leading to an increased risk of pseudarthrosis. It seems there's no text provided in your request to paraphrase. Please provide the content you want to be rephrased, and I'll be happy to assist you!
Long-term follow-up studies indicate that patient-reported results—such as Neck Disability Index (NDI), Visual Analogue Scale (VAS) pain scores, and SF-36 assessments—show lasting advantages for 5 to 10 years post-surgery. Nonetheless, some patients demonstrate a gradual return of symptoms or functional deterioration over time, often linked to adjacent segment disease (ASD), believed to result from changed biomechanics post-fusion. Nonetheless, overall satisfaction levels stay elevated, and most patients exhibit considerable enhancement in relation to their preoperative condition

7. Complications

Complication	**Approximate Incidence**
Dysphagia	5–20% (often transient)
Pseudarthrosis	2–10% (higher in multilevel)
Adjacent segment degeneration	8–25% over 10 years

Hardware failure	2–3%
Recurrent laryngeal nerve palsy	1–3%
Infection	1–2%
Esophageal injury	0.2–0.5%
Vertebral artery injury	0.1–0.5%

Table 1: Indicates the complication and the approximate incidence [20]

Comparison with Alternative Approaches

Posterior Cervical Foraminotomy(PCF):

Posterior cervical foraminotomy is a motion-preserving procedure primarily indicated for single-level cervical radiculopathy caused by foraminal stenosis or lateral disc herniation. Multiple randomized controlled trials have shown that PCF provides comparable symptomatic relief to ACDF in properly selected patients, while avoiding the need for fusion and its associated risks such as pseudarthrosis and adjacent segment degeneration. The procedure preserves the native disc and cervical alignment, allowing maintenance of segmental motion. However, it does not address central canal stenosis or ventral compressive pathology, and there is a higher chance of recurrent symptoms if central degeneration progresses. [21]

Cervical Corpectomy:

Cervical corpectomy consists of excising one or multiple vertebral bodies along with the surrounding discs to relieve pressure on the spinal cord in situations of multi-level compression, ossification of the posterior longitudinal ligament (OPLL), or conditions affecting vertebral bodies like tumors or fractures. This method permits direct relief of central canal issues extending beyond the vertebral body; however, it is more challenging than ACDF and leads to increased intraoperative blood loss, extended surgery durations, and elevated occurrences of graft subsidence and pseudarthrosis, especially in multilevel cases. In contrast to multilevel ACDF, corpectomy might offer more thorough decompression but comes with heightened surgical morbidity.[22]

Cervical Disc Arthroplasty(CDA):

Cervical disc arthroplasty aims to maintain motion at the treated level while offering neural decompression, potentially decreasing the likelihood of adjacent segment degeneration observed after fusion surgeries. Present evidence indicates that CDA provides comparable or marginally better functional results than ACDF in younger individuals with single-level conditions who exhibit minimal spondylosis and maintained segmental motion before surgery. Contraindications consist of severe degenerative alterations, facet joint disease, and considerable instability. Extended research indicates that CDA might postpone or avert degeneration at nearby levels, yet factors like expense, implant durability, and revision approaches are still important in choosing patients

Future Directions:

Innovations in ACDF technology are progressively aimed at boosting fusion rates, reducing complications, and optimizing patient recovery. Cervical cages made from porous titanium are being designed to enhance osseointegration while maintaining ideal load-sharing characteristics through biomechanical optimization. Independent cage-plate systems seek to deliver adequate stability without requiring additional anterior plates, which may lessen postoperative dysphagia. Utilizing stem cell–boosted bone graft substitutes shows potential for speeding up bone healing and facilitating earlier fusion, especially in high-risk or multilevel scenarios. Moreover, completely endoscopic anterior techniques are being explored to lessen soft tissue damage, decrease perioperative complications, and promote quicker recovery, potentially reshaping the surgical benchmark for cervical degenerative conditions.

Conclusion:-

ACDF remains a cornerstone in the management of cervical spine disorders, offering high rates of neurological improvement and spinal stability. Proper patient selection, meticulous surgical technique, and appropriate choice of graft and instrumentation are key to optimizing outcomes. The evolution of minimally invasive techniques and motion-preserving alternatives may redefine surgical paradigms in the coming decades.

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