ISSN 1220-8841 (Print)
ISSN 2344-4959 (Online)

ROMANIAN
NEUROSURGERY

Vol. XXXVIII | No. 2 June 2024

# A comprehensive review on anterior endoscopic cervical discectomy

Muhammad Jehanzeb,
Ahtesham Khizar,
Inaam Elahi

DOI: 10.33962/roneuro-2024-042

Romanian Neurosurgery (2024) XXXVIII (2): pp. 242-256
DOI: 10.33962/roneuro-2024-042
www.journals.lapub.co.uk/index.php/roneurosurgery

# A comprehensive review on anterior endoscopic cervical discectomy

**Muhammad Jehanzeb, Ahtesham Khizar, Inaam Elahi**

Punjab Institute of Neurosciences, Lahore, PAKISTAN

## ABSTRACT

Anterior endoscopic cervical discectomy (AECD) represents a groundbreaking surgical technique that has garnered considerable interest in recent times due to its minimally invasive nature for addressing cervical disc herniation. This review endeavours to conduct a thorough examination of the existing literature concerning AECD, encompassing its indications, surgical technique, clinical outcomes, advantages, limitations, and potential complications. Through a meticulous analysis of the available data, this review aims to evaluate the effectiveness, safety, and overall viability of AECD as a substitute for conventional open surgical methods in addressing cervical disc issues. By delving into these aspects, the review seeks to provide insights into the potential role of AECD in enhancing patient outcomes and optimizing the management of cervical disc pathology.

Keywords
cervical spine,
cervical spondylosis,
discectomy,
endoscopy

## INTRODUCTION

Cervical disc herniation is a common cause of neck and upper limb pain, often leading to neurological symptoms and functional impairment. Traditional open surgical techniques, such as anterior cervical discectomy and fusion (ACDF), have been widely used for the treatment of cervical disc herniation. However, these procedures involve extensive tissue dissection, muscle retraction, and fusion, which can result in complications, prolonged recovery times, and potential limitations in spinal motion.[1,2] The development of endoscopic technologies has paved the way for minimally invasive approaches to cervical disc herniation. Anterior endoscopic cervical discectomy (AECD) is a novel technique that aims to minimize tissue trauma while providing effective decompression of the affected disc level. AECD involves accessing the cervical spine through small incisions and using specialized endoscopic instruments to visualize and remove the herniated disc material.[3,4]

The rationale for AECD lies in its potential to achieve similar clinical outcomes as traditional open surgeries while minimizing the associated drawbacks. By avoiding extensive tissue disruption and preserving spinal stability, AECD offers the promise of reduced postoperative pain, shorter hospital stays, faster recovery, and improved patient satisfaction. Additionally, the preservation of spinal motion and

Corresponding author:
**Ahtesham Khizar**

Punjab Institute of Neurosciences, Lahore, Pakistan

arwain.6n2@gmail.com



ISSN online 2344-4959
© Romanian Society of Neurosurgery

First published
June 2024 by
London Academic Publishing
www.lapub.co.uk

adjacent segment integrity are important considerations in the long-term success of cervical disc surgery.[5,6] The growing body of literature on AECD highlights its potential advantages over open surgical techniques. Several studies have reported favorable clinical outcomes, including significant pain relief, improvement in neurological function, and high patient satisfaction rates. Furthermore, AECD has demonstrated advantages such as reduced blood loss, decreased postoperative complications, and improved cosmetic outcomes.

It is also important to acknowledge that AECD is a technically demanding procedure requiring specialized training and expertise. Surgeon experience and patient selection criteria play crucial roles in achieving optimal outcomes. Additionally, long-term follow-up data are still limited, and comparative studies with traditional open surgeries and other minimally invasive techniques are necessary to establish the true efficacy and safety of AECD. In short, AECD represents a promising advancement in the management of cervical disc herniation. Its minimally invasive nature, potential for reduced tissue trauma, and preservation of spinal motion make it an appealing option for both patients and surgeons. However, further research and well-designed studies are needed to establish its long-term outcomes, comparative effectiveness, and potential role as a standard surgical approach for cervical disc pathology.

## Discussion

**Evolution of surgical techniques for cervical disc herniation:**

The surgical management of cervical disc herniation has evolved over the years, with various techniques being developed to improve outcomes and minimize surgical invasiveness. Key milestones in the evolution of surgical techniques for cervical disc herniation are discussed below:

1. **Anterior cervical discectomy and fusion (ACDF):** ACDF has been the traditional surgical approach for cervical disc herniation. It involves the removal of the herniated disc material through an anterior approach, followed by the placement of a bone graft and anterior plate fixation to achieve spinal fusion. ACDF has shown favorable outcomes in terms of pain relief and neurological improvement.[1] However, concerns about adjacent segment degeneration and limited motion preservation have led to the exploration of alternative techniques.

2. **Posterior cervical foraminotomy:** Posterior cervical foraminotomy is a minimally invasive technique that aims to decompress the nerve root by removing the osteophytes and part of the facet joint. This approach allows for direct visualization of the nerve root and preservation of motion segments. Studies have demonstrated comparable outcomes to ACDF in terms of pain relief and functional improvement.[7]

3. **Cervical disc arthroplasty:** Cervical disc arthroplasty, also known as total disc replacement, involves the removal of the diseased disc and the implantation of an artificial disc prosthesis. This technique aims to preserve motion at the treated level and potentially reduce the risk of adjacent segment degeneration. Several studies have shown favorable clinical outcomes with cervical disc arthroplasty, including improved range of motion and similar or better pain relief compared to fusion techniques.[8,9]

4. **Minimally invasive approaches:** Advancements in endoscopic and minimally invasive techniques have revolutionized the field of cervical spine surgery. These approaches, such as AECD, utilize smaller incisions, specialized instruments, and endoscopic visualization to achieve decompression while minimizing tissue disruption. Minimally invasive techniques have been associated with reduced postoperative pain, shorter hospital stays, and faster recovery compared to open procedures.

5. **Full-endoscopic techniques:** Full-endoscopic techniques have gained popularity in recent years for the treatment of cervical disc herniation. These approaches utilize specialized endoscopic instruments to directly visualize and access the herniated disc through a small incision. Full-endoscopic techniques, such as full-endoscopic cervical discectomy, offer the advantages of minimal tissue disruption, reduced postoperative pain, and faster recovery.[3]

6. **Hybrid techniques:** Hybrid techniques combine elements of different surgical approaches to optimize outcomes. For example, hybrid

procedures may involve a combination of anterior and posterior approaches to achieve decompression and stabilization. These techniques aim to address specific pathology while minimizing invasiveness and preserving spinal function.

7. **Navigation-assisted techniques:** Navigation-assisted techniques utilize intraoperative navigation systems to enhance the accuracy and safety of surgical procedures. These systems provide real-time imaging guidance, improving the precision of implant placement and facilitating optimal decompression. Navigation-assisted techniques have shown potential in improving surgical outcomes and reducing complications.

**Indications for AECD:**

AECD has shown promising outcomes in specific indications. Common indications for AECD are:

1. **Cervical disc herniation:** AECD is commonly performed for the treatment of cervical disc herniation. It is particularly effective in cases where the herniation is causing compression of the spinal cord or nerve roots, resulting in radicular symptoms such as neck pain, arm pain, numbness, or weakness. AECD allows for direct visualization and precise removal of the herniated disc, relieving pressure on the neural structures.

2. **Cervical radiculopathy:** Cervical radiculo-pathy refers to the compression or irritation of a nerve root in the cervical spine, leading to radiating pain, numbness, and weakness in the corresponding upper extremity. AECD can be a suitable treatment option for cervical radiculopathy caused by disc herniation, as it provides targeted decompression of the affected nerve root.[10]

3. **Cervical myelopathy:** Cervical myelopathy is a condition characterized by compression of the spinal cord in the cervical spine, resulting in motor deficits, sensory changes, and loss of coordination. In selected cases of cervical myelopathy caused by disc herniation, AECD may be considered as a treatment option. The removal of the herniated disc material can relieve spinal cord compression and potentially improve neurological function.

4. **Failed conservative treatment:** AECD may be recommended when conservative treatments, such as medication, physical therapy, or spinal injections, have failed to provide adequate relief from symptoms and there is persistent pain or functional impairment. In such cases, AECD offers a minimally invasive surgical option to address the underlying pathology and alleviate symptoms.

**Patient selection criteria:**

Patient selection plays a crucial role in determining the success and safety of AECD. Proper patient selection ensures that individuals who are most likely to benefit from the procedure are chosen. While specific criteria may vary among surgeons and institutions, some general patient selection considerations for AECD are:

1. **Symptomatic disc herniation:** AECD is typically recommended for patients with symptomatic cervical disc herniation causing radicular symptoms, such as neck pain, arm pain, numbness, or weakness. Imaging studies, such as magnetic resonance imaging (MRI), should confirm the presence of disc herniation correlating with the patient's symptoms.[11]

1. **Failed conservative treatment:** Patients who have failed to respond to conservative treatments, including medication, physical therapy, and spinal injections, may be considered for AECD. A trial of conservative treatment for a reasonable duration should be undertaken before considering surgical intervention.

2. **Neurological deficits:** Patients with neurological deficits, such as muscle weakness, sensory changes, or coordination problems, caused by cervical disc herniation may be candidates for AECD. The presence and severity of neurological deficits should be evaluated through clinical examination and neuroimaging.

3. **Single-level disc herniation:** AECD is commonly performed for single-level disc herniation. Patients with a clear correlation between their

symptoms and a single-level disc herniation are considered suitable candidates. Multilevel herniations or complex pathologies may require alternative surgical approaches.

4. **Absence of severe instability:** Patients with severe cervical spine instability, such as significant spondylolisthesis or degenerative cervical kyphosis, may not be suitable candidates for AECD. Preoperative evaluation of cervical spine stability, including dynamic imaging, can help identify patients who require alternative surgical interventions.

5. **Recurrent disc herniation:** AECD can be considered as a treatment option for patients with recurrent disc herniation in the cervical spine. Recurrent disc herniation refers to the recurrence of herniation at the same level or adjacent levels following previous surgical intervention. AECD allows for targeted removal of the recurrent herniated disc material, providing symptom relief and reducing the need for more extensive revision surgeries.

6. **Favorable anatomy:** Patients with favorable anatomical characteristics, such as adequate access to the target disc space and sufficient disc height, are more likely to be suitable candidates for AECD. Preoperative imaging studies, including lateral radiographs and magnetic resonance imaging (MRI), can help assess the feasibility of the procedure based on the patient's anatomy.[12]

7. **Absence of ossification of the posterior longitudinal ligament (OPLL):** Patients with severe OPLL may not be appropriate candidates for AECD. OPLL can limit the ability to adequately visualize and access the herniated disc during the endoscopic procedure. Preoperative imaging, such as computed tomography (CT) or MRI, should be performed to evaluate the extent and severity of OPLL

8. **Adequate surgical experience:** AECD is a technically demanding procedure that requires specific surgical skills and expertise. Surgeons should have sufficient training and experience in performing endoscopic cervical discectomy to ensure optimal outcomes and minimize complications. Patients should seek surgeons who are well-versed in endoscopic techniques and have a track record of successful AECD procedures.

**Cervical disc herniation types amenable to AECD:** Some common types of cervical disc herniation that are amenable to AECD are:

1. **Posterolateral disc herniation:** AECD is suitable for treating posterolateral disc herniation, where the herniated disc material protrudes toward the side of the spinal canal. This type of disc herniation can cause compression of the nerve roots, resulting in radicular symptoms. AECD allows for direct visualization and removal of the herniated disc material through an anterior approach.[13]

2. **Central disc herniation:** AECD can also be used for central disc herniation, where the herniation occurs centrally within the spinal canal, causing compression of the spinal cord. In selected cases, AECD can be performed to decompress the spinal cord by removing the herniated disc material and relieving the pressure on the spinal cord.[13]

3. **Subligamentous disc herniation:** Subligamentous disc herniation refers to a herniated disc that is located beneath the posterior longitudinal ligament (PLL). AECD can be utilized to access and remove the subligamentous disc herniation while preserving the PLL. This approach avoids disruption of the PLL, which may help maintain spinal stability.

**Surgical technique:**

**a. Preoperative planning and patient positioning:** Preoperative planning and patient positioning are crucial aspects of AECD to ensure a successful procedure. An overview of the preoperative planning and patient positioning is given below:

1. **Preoperative imaging:** Preoperative imaging, such as MRI or CT scans, helps in evaluating the extent and location of the disc herniation, identifying any associated pathologies, and planning the surgical approach.[13]

2. **Neurological evaluation:** A comprehensive neurological evaluation is performed to assess the patient's symptoms, neurological deficits, and functional limitations. It helps determine the

indication for surgery and provides a baseline for postoperative comparison.

3. **Informed consent and patient education:** The surgeon should have a detailed discussion with the patient, explaining the procedure, potential risks, benefits, and possible complications. Informed consent should be obtained, and the patient should be educated about preoperative and postoperative care.

4. **Patient positioning:** Proper patient positioning is crucial for optimal access to the surgical site and to minimize the risk of complications. The patient is usually positioned supine on the operating table with the neck slightly extended. Various positioning aids, such as a headrest or a horseshoe-shaped headrest, may be used to stabilize the head and maintain proper alignment during the procedure.

**b. Access routes and portal placement:** Access routes and portal placement are important considerations in AECD to ensure safe and effective access to the surgical site.

1. **Access routes:** The access route refers to the path taken to reach the targeted disc level. In AECD, the most common access routes include the anterior approach through the intervertebral disc space or the lateral approach through the uncovertebral joint. The choice of access route depends on the specific anatomical considerations and surgeon preference.

2. **Portal placement:** Portal placement involves creating small incisions for the introduction of endoscopic instruments and visualization. The exact placement of portals may vary depending on the targeted disc level and the specific technique used. Typically, the portals are strategically placed to provide optimal access, visualization, and instrument maneuverability.

**c. Step-by-step procedure description:** Surgical technique for AECD is given below:

1. **Patient positioning and anesthesia:** The patient is placed in a supine position on the operating table, and general anesthesia is administered to ensure comfort and immobility during the procedure.

2. **Incision and exposure:** A small incision is made in the anterior neck, typically along a natural skin crease. The subplatysmal plane is dissected to expose the anterior cervical spine.

3. **Dilating and portal creation:** Sequential dilators or tubular retractors are used to create a working channel to the targeted disc space. This allows for visualization and instrument access to the disc.

4. **Discectomy and decompression:** Endoscopic instruments, such as a microendoscope or endoscopic forceps, are introduced through the portals. The herniated disc material is visualized and carefully removed, relieving pressure on the spinal cord or nerve roots.

5. **Visualization and confirmation:** Throughout the procedure, a high-definition endoscope or camera is used to provide visualization of the surgical site. This allows the surgeon to ensure complete decompression and confirm the appropriate removal of the herniated disc.

6. **Closure:** After the completion of the discectomy, the instruments are removed, and the incision is closed using sutures or surgical staples. Sterile dressings are applied to the incision site.

**d. Intraoperative considerations and precautions:** During AECD, several intraoperative considerations and precautions should be taken to ensure patient safety and successful outcomes. Some common intraoperative considerations are given below:

1. **Neural structures identification and protection:** Careful identification and protection of neural structures, such as the spinal cord and nerve roots, are crucial during AECD. Visualization and gentle retraction techniques help minimize the risk of inadvertent injury to these structures.

2. **Hemostasis:** Adequate hemostasis is essential to minimize bleeding during the procedure. Hemostatic agents, cautery techniques, and meticulous dissection can be used to achieve hemostasis and maintain a clear surgical field.

3. **Complete discectomy:** Thorough removal of the herniated disc material is crucial to ensure decompression of neural structures and reduce the risk of recurrence. Visualization through the endoscope and careful inspection of the disc space help ensure complete discectomy.

4. **Spinal stability:** Preservation of spinal stability is important during AECD. Depending on the patient's condition and surgeon's preference, additional procedures such as fusion or artificial disc replacement may be considered to maintain spinal stability.

5. **Neurophysiological monitoring:** Intraoperative neurophysiological monitoring, such as somatosensory evoked potentials (SSEP) and electromyography (EMG), may be employed to assess the integrity of neural structures and guide surgical decision-making.

**Clinical outcomes:**

a. **Pain relief and functional improvement:** The clinical outcome of AECD is often evaluated in terms of pain relief and functional improvement. Ruetten S et al.[3] compared the clinical outcomes of full-endoscopic anterior decompression (including AECD) with conventional anterior decompression and fusion. The authors found that both approaches provided significant pain relief and functional improvement, but the full-endoscopic approach resulted in a lower complication rate and faster recovery.

b. **Rates of neurological recovery:** Ruetten S et al.[3] compared the neurological recovery rates between full-endoscopic anterior decompression (including AECD) and conventional anterior decompression and fusion. The authors reported significant neurological improvement in both groups, but the full-endoscopic approach resulted in a lower complication rate and faster recovery.

c. **Return to work and quality of life measures:** In this study by Ruetten S et al.[3], the authors compared full-endoscopic anterior decompression (including AECD) with conventional anterior decompression and fusion. They reported a faster return to work and improved quality of life in the full-endoscopic group compared to the conventional group.

d. **Comparison with open surgical approaches:** When comparing AECD with open surgical approaches for the treatment of cervical disc herniation, several factors come into consideration. Some aspects to be considered when comparing AECD with open surgical approaches are:

1. **Surgical approach:** AECD is a minimally invasive procedure that utilizes an endoscope to access and remove the herniated disc material through a small incision. In contrast, open surgical approaches typically involve a larger incision and require more extensive tissue dissection to access the affected disc.

2. **Muscle and tissue trauma:** AECD is associated with reduced muscle and tissue trauma compared to open surgical approaches. The smaller incision and targeted approach of AECD minimize disruption to surrounding structures, leading to potentially faster recovery and reduced postoperative pain.

3. **Blood loss and complications:** AECD is generally associated with less blood loss compared to open surgical approaches. The reduced tissue trauma and smaller incision contribute to lower complication rates, such as infection and wound healing problems, in AECD.

4. **Operative time:** AECD typically requires a shorter operative time compared to open surgical approaches. The minimally invasive nature of AECD allows for a more focused and streamlined procedure, potentially resulting in shorter surgical durations.

5. **Hospital stay and recovery:** AECD is often associated with shorter hospital stays compared to open surgical approaches. Patients undergoing AECD may experience faster recovery and return to their daily activities, including work, compared to those undergoing open surgical procedures.

6. **Long-term outcomes:** Both AECD and open surgical approaches have shown favorable long-term outcomes in terms of pain relief, functional improvement, and patient satisfaction. However, long-term studies directly comparing the two

approaches are limited, and further research is needed to fully assess the comparative effectiveness and long-term outcomes.

**Advantages of AECD:**

**a. Minimally invasive nature:** One of the key advantages of AECD is its minimally invasive nature. Some points highlighting the benefits of the minimally invasive approach are:

1. **Reduced tissue trauma:** AECD involves a smaller incision and uses endoscopic techniques to access the cervical disc herniation. This results in reduced tissue trauma compared to traditional open surgical approaches. The smaller incision minimizes disruption to surrounding muscles, ligaments, and other soft tissues, leading to less postoperative pain and faster recovery.
2. **Decreased blood loss:** The minimally invasive nature of AECD results in reduced blood loss during the procedure. This can lead to a lower risk of complications related to blood loss and the need for blood transfusions.
3. **Smaller incision and minimal scarring:** AECD utilizes a smaller incision compared to open surgical approaches. This results in a more favorable cosmetic outcome with minimal scarring. The smaller incision size is particularly advantageous for patients who value aesthetic considerations.
4. **Faster recovery and shorter hospital stay:** The minimally invasive nature of AECD leads to faster recovery and shorter hospital stays compared to open surgical approaches. Patients may experience reduced postoperative pain, require fewer pain medications, and be able to resume their daily activities sooner.

**b. Preservation of cervical spine stability:** Another advantage of AECD is the preservation of cervical spine stability. Some points highlighting this benefit are:

1. **Preservation of natural spinal anatomy:** AECD allows for targeted removal of the herniated disc material while preserving the integrity of the surrounding spinal structures. This includes preserving the facet joints, posterior ligaments, and adjacent vertebral bodies. By maintaining the natural anatomy, AECD helps to preserve the stability of the cervical spine.
2. **Reduced risk of postoperative instability:** The preservation of spinal structures through AECD can help minimize the risk of postoperative instability. This is particularly important in cases where the disc herniation is associated with minimal or no significant degenerative changes in the adjacent vertebral segments.
3. **Avoidance of adjacent segment degeneration:** By preserving the natural spinal anatomy and minimizing the extent of surgery, AECD can potentially reduce the risk of adjacent segment degeneration. This refers to the accelerated degeneration that may occur in the vertebral segments adjacent to the treated level following spinal fusion procedures.
4. **Potential for motion preservation:** In some cases, AECD may allow for preservation of motion at the treated level, depending on the specific technique employed. This can be advantageous for maintaining normal neck motion and potentially reducing the risk of adjacent segment degeneration associated with spinal fusion procedures.

**c. Reduced blood loss and tissue trauma:** Reduced blood loss and tissue trauma are significant advantages of AECD. An overview of these benefits is:

1. **Reduced blood loss:** AECD is a minimally invasive procedure that involves a smaller incision and utilizes endoscopic techniques. Compared to traditional open surgical approaches, AECD typically results in reduced blood loss during the procedure. This can lead to several advantages, including a lower risk of complications related to blood loss and potentially less need for blood transfusions.
2. **Minimal tissue trauma:** AECD is designed to minimize disruption to the surrounding tissues, including muscles, ligaments, and other soft tissues. The smaller incision used in AECD reduces the extent of tissue trauma compared to open surgical approaches. As a result, patients may experience less postoperative pain, have a

faster recovery, and require shorter hospital stays.

3. **Preservation of surrounding structures:** AECD focuses on assessing and treating the herniated disc material while preserving the integrity of the surrounding spinal structures. By avoiding excessive tissue disruption, the procedure aims to minimize trauma to the adjacent muscles, ligaments, and bones. This can contribute to reduced postoperative pain and faster recovery.

4. **Improved cosmetic outcome:** The smaller incision used in AECD results in a more favorable cosmetic outcome compared to larger incisions associated with open surgical approaches. The reduced tissue trauma and smaller scar contribute to improved cosmetic appearance, which may be particularly important for patients who value aesthetic considerations.

**d. Shorter hospital stay and faster recovery:** Shorter hospital stay and faster recovery are significant advantages of AECD. An overview of these benefits is:

1. **Shorter hospital stay:** AECD is a minimally invasive procedure that is associated with shorter hospital stays compared to traditional open surgical approaches. The smaller incision and reduced tissue trauma associated with AECD often result in less postoperative pain and faster recovery. This allows patients to be discharged from the hospital earlier, leading to a shorter overall hospital stay.[14]

2. **Faster recovery:** AECD minimizes disruption to the surrounding tissues, including muscles, ligaments, and other soft tissues. As a result, patients may experience less postoperative pain and have a faster recovery compared to open surgical approaches. The minimally invasive nature of AECD promotes early mobilization, allowing patients to resume their daily activities sooner.

3. **Reduced postoperative complications:** AECD's shorter hospital stay and faster recovery can contribute to a reduced risk of postoperative complications. Prolonged hospital stays are associated with an increased risk of healthcare-associated infections and other complications. By minimizing the duration of hospitalization, AECD helps to lower the overall risk of these complications.

4. **Improved patient satisfaction:** The shorter hospital stay and faster recovery associated with AECD can enhance patient satisfaction. Patients often prefer minimally invasive procedures that allow them to return to their normal activities quickly and with minimal disruption to their daily lives. AECD's ability to offer a faster recovery can positively impact patients' overall experience and satisfaction with the procedure.[14]

**e. Cosmetic benefits and patient satisfaction:** Cosmetic benefits and patient satisfaction are important considerations when evaluating the advantages of AECD. An overview of these benefits is:

1. **Minimal scarring:** AECD is a minimally invasive procedure that involves smaller incisions compared to open surgical approaches. The use of smaller incisions results in minimal scarring, which can be cosmetically advantageous. The smaller scars are often less noticeable and may be better concealed, leading to improved cosmetic outcomes and patient satisfaction.

2. **Aesthetically pleasing results:** AECD's minimally invasive approach and smaller incisions contribute to aesthetically pleasing results. Patients may feel more confident and satisfied with the appearance of their neck following the procedure, as the minimal scarring and preservation of natural tissue structures enhance the overall aesthetic outcome.

3. **Psychological well-being:** The cosmetic benefits of AECD can have a positive impact on a patient's psychological well-being and self-esteem. Patients may experience improved body image and reduced self-consciousness about visible scars, leading to enhanced satisfaction with their overall appearance and improved quality of life.

4. **Overall patient satisfaction:** The combination of reduced scarring, improved aesthetic outcomes, and enhanced psychological well-being contributes to overall patient satisfaction with AECD. Patients appreciate the cosmetic benefits of the procedure, which can positively

influence their perception of the surgical experience and outcomes.

**Limitations and challenges:**

**a. Learning curve and surgeon expertise:** Learning curve and surgeon expertise are important factors to consider in AECD, and they come with certain limitations and challenges. Some key points to consider are:

1. **Learning curve:** AECD is a technically demanding procedure that requires specialized training and experience. Surgeons must develop proficiency in endoscopic techniques and become familiar with the specific equipment used in AECD. The learning curve for AECD can be steep, and it may take time for surgeons to gain the necessary skills and expertise to perform the procedure effectively.[15]

2. **Surgeon expertise:** The success of AECD heavily relies on the expertise and skill of the surgeon performing the procedure. Surgeons with extensive experience in endoscopic spine surgery and a deep understanding of cervical anatomy are better equipped to handle the complexities and potential complications that may arise during AECD. Therefore, it is crucial for patients to seek out surgeons who have a proven track record and specialized training in AECD.

3. **Learning curve-related complications:** During the initial stages of the learning curve, surgeons may encounter higher rates of complications compared to experienced surgeons. This includes the risk of inadvertent damage to vital structures, suboptimal decompression, or incomplete removal of disc material. As surgeons gain experience and refine their skills, the rates of these complications typically decrease.[16]

4. **Patient selection and case complexity:** Surgeon expertise is particularly crucial in appropriately selecting patients for AECD and assessing the complexity of each case. Not all patients with cervical disc herniation may be suitable candidates for AECD, especially those with extensive pathology, instability, or significant spinal cord compression. Surgeons with expertise in AECD can accurately evaluate patient eligibility and identify cases that may require alternative surgical approaches.[16]

**b. Patient-specific anatomical variations:** Patient-specific anatomical variations can present challenges during AECD. Some key considerations are:

1. **Vertebral anatomy:** The anatomy of the cervical vertebrae can vary among individuals, including the size, shape, and orientation of the vertebral bodies, facet joints, and neural foramina. These anatomical variations can affect the accessibility and visualization of the targeted disc space during AECD. Surgeons need to be mindful of these variations and adapt their surgical approach accordingly.

2. **Disc morphology and pathology:** The morphology and pathology of the cervical discs can also vary among patients. The location, size, and extent of the disc herniation or degeneration can differ, making each case unique. Surgeons need to carefully assess the patient's specific disc pathology and customize the surgical approach and technique accordingly to achieve optimal outcomes.

3. **Neurovascular structures:** Anatomical variations of the neurovascular structures in the cervical region, such as the vertebral artery and spinal nerves, can pose challenges during AECD. Surgeons must have a detailed understanding of the patient's specific neurovascular anatomy to minimize the risk of injury during the procedure.

4. **Adjacent level anatomy:** Patient-specific variations in the adjacent cervical levels, including the disc height, facet joint morphology, and presence of osteophytes, can impact the surgical approach and technique during AECD. Surgeons must carefully assess the anatomy of the adjacent levels to ensure proper planning and execution of the procedure.

**c. Potential complications and their management:** AECD is generally considered a safe procedure, but like any surgical intervention, it carries potential complications. Some common complications that can occur during or after AECD, along with their management are:

1. **Nerve injury:** Nerve injury, including spinal nerve root or spinal cord injury, can occur during AECD. Surgeons must exercise caution to minimize the risk of nerve damage. In the event of nerve injury, prompt recognition and appropriate management are crucial. Neurological deficits should be evaluated, and if necessary, further imaging studies and consultation with a neurosurgeon or spine specialist should be considered.[17]

2. **Vascular injury:** Vascular injury, such as injury to the vertebral artery or carotid artery, is a potential complication during AECD. Surgeons should be vigilant to minimize the risk of vascular injury. In case of vascular injury, immediate recognition and intervention are crucial. Vascular surgery consultation may be necessary for management, including potential repair or embolization of the injured vessel.

3. **Infection:** Surgical site infection can occur after AECD. Strict adherence to aseptic techniques, proper wound care, and prophylactic antibiotics can help reduce the risk of infection. If an infection occurs, appropriate antibiotic therapy and wound management are essential. In some cases, surgical debridement or drainage may be necessary.

4. **Disc recurrence:** In some cases, there may be a recurrence of disc herniation at the treated level following AECD. Patients should be educated about the possibility of disc recurrence and the need for ongoing monitoring. In case of recurrence, further imaging studies, such as MRI, should be performed to assess the extent of recurrence and guide subsequent treatment decisions.

5. **Dysphagia and hoarseness:** AECD can occasionally lead to postoperative dysphagia (difficulty swallowing) and hoarseness due to irritation or injury to the esophagus or recurrent laryngeal nerve. These symptoms are typically temporary and resolve spontaneously over time. Symptomatic management, such as dietary modifications or voice therapy, may be appropriate in certain cases.[17,18]

6. **Instrumentation-related complications:** Instrumentation-related complications can include implant migration, malposition, or failure. Surgeons must carefully select appropriate implants and ensure their correct placement and fixation. In case of instrumentation-related complications, revision surgery may be required to address the issue, such as repositioning or replacing the implant.

7. **Adjacent segment degeneration:** AECD can lead to increased stress and motion at adjacent cervical levels, potentially contributing to adjacent segment degeneration (ASD) over time. Close follow-up and monitoring of patients are essential to identify and manage the development of ASD. Non-operative measures such as physical therapy or pain management can be considered initially, but in some cases, surgical intervention may be necessary.[17]

**Comparative Analysis:**

**a. AECD versus traditional open discectomy:** Comparison between AECD and traditional open discectomy is an important aspect to consider when evaluating the surgical options for cervical disc herniation. Some points of comparison between the two techniques are shown in the following table:

| S.no. | Features | ACED | Traditional Open Discectomy |
|---|---|---|---|
| 1. | Surgical Approach | Anterior endoscopic cervical discectomy is a minimally invasive procedure performed through a small incision in the front of the neck. It utilizes an endoscope and specialized instruments to access and remove the herniated disc material. | This technique involves a larger incision in the front or back of the neck, allowing direct visualization of the affected disc and removal of the herniated portion. |
| 2. | Tissue Trauma | AECD involves less tissue trauma and | Open discectomy |

| | | | |
|---|---|---|---|
| | and Muscle Dissection | muscle dissection compared to open discectomy. The smaller incision and use of endoscopic instruments help minimize damage to surrounding structures. | involves more extensive tissue dissection, which can lead to increased muscle trauma and potential for postoperative pain and complications. |
| 3. | Visualization and Magnification | The use of an endoscope provides magnified visualization of the surgical site, allowing for better identification and removal of the herniated disc material. | Open discectomy provides direct visualization of the surgical site, but the magnification is limited compared to endoscopic techniques. |
| 4. | Hospital Stay and Recovery | Minimally invasive nature of AECD usually leads to shorter hospital stays and faster recovery times compared to open discectomy. | Open discectomy may require a longer hospital stay and recovery period due to the larger incision and associated tissue trauma. |
| 5. | Complications | AECD is associated with its own set of potential complications, such as nerve injury, vascular injury, infection, and recurrence of disc herniation. However, the overall complication rates are generally reported to be low. | Open discectomy also carries potential complications such as nerve damage, infection, blood loss, and scar formation. |

**b. Cost-effectiveness considerations:** Cost-effectiveness is an important aspect to consider when evaluating medical interventions such as AECD and traditional open discectomy. Some general considerations regarding cost-effectiveness in the context of AECD are:

1. **Direct costs:** Direct costs include hospitalization costs, surgical fees, anesthesia fees, and postoperative care expenses. AECD is often associated with shorter hospital stays and faster recovery times compared to traditional open discectomy. This can potentially result in lower direct costs for AECD due to reduced resource utilization.
2. **Indirect costs:** Indirect costs encompass factors such as lost productivity, time off work, and rehabilitation expenses. Minimally invasive techniques like AECD may offer advantages in terms of shorter recovery times, allowing patients to return to work and daily activities sooner, potentially reducing indirect costs associated with lost productivity.
3. **Complications and reoperation rates:** The occurrence of complications and the need for reoperation can significantly impact the overall cost-effectiveness of a surgical intervention. While AECD is generally associated with lower complication rates compared to open discectomy, it is crucial to consider the long-term outcomes, including the potential need for revision surgery, as these factors can influence the cost-effectiveness of AECD.
4. **Health-related quality of life:** Assessing health-related quality of life is an essential component of cost-effectiveness analysis. While AECD and traditional open discectomy aim to provide pain relief and functional improvement, evaluating the long-term impact on quality of life is important when considering the cost-effectiveness of the procedures.

**Future directions and innovations:**

**a. Advances in endoscopic technology:** Advances in endoscopic technology have significantly contributed to the field of minimally invasive spine surgery, including AECD. These advancements have improved visualization, instrumentation, and procedural techniques, enhancing the safety and efficacy of endoscopic procedures. Some notable advances in endoscopic technology include:

1. **High-definition imaging:** Modern endoscopic systems employ high-definition cameras that provide excellent visualization of the surgical field. This allows surgeons to navigate and perform precise interventions with enhanced clarity and detail.[16]

2. **Miniaturized instruments:** Endoscopic instruments have become increasingly compact and specialized, enabling surgeons to access and manipulate anatomical structures through small incisions. These instruments often incorporate advanced features such as adjustable angles, ergonomic handles, and improved durability.

3. **Improved lighting and visualization systems:** Endoscopic systems now incorporate advanced lighting technologies, such as xenon or LED light sources, to provide optimal illumination during surgery. Coupled with high-definition cameras and monitors, these systems enable clear visualization of the surgical field, even in deep or narrow anatomical spaces.[16]

4. **Navigation and robotics:** Endoscopic procedures can benefit from the integration of navigation and robotic technologies. Navigation systems utilize real-time imaging and tracking to assist surgeons in precise instrument guidance and localization within the spine. Robotic systems can enhance surgical accuracy and facilitate complex maneuvers by providing assistance and precision control to the surgeon.

5. **Surgical training simulators:** Virtual reality-based simulators and training modules have been developed to enhance the education and skill development of surgeons performing endoscopic procedures. These simulators allow surgeons to practice surgical techniques in a controlled environment, improving their proficiency and reducing the learning curve.

6. **Tissue management:** Advancements in endoscopic technology have led to the development of specialized tools for tissue management, including bipolar radiofrequency ablation and laser systems. These tools enable efficient and controlled tissue ablation, minimizing the risk of injury to surrounding structures.

**b. Training and education for widespread adoption:** Training and education are crucial factors for the widespread adoption of AECD and other advanced endoscopic spine surgery techniques. Few key points related to training and education in AECD are:

1. **Specialized training programs:** Surgeons interested in AECD should undergo specialized training programs to gain the necessary knowledge and skills. These programs typically include didactic sessions, hands-on workshops, and observation of experienced surgeons performing AECD procedures. This allows surgeons to understand the surgical technique, become familiar with the instruments and equipment, and develop proficiency in performing the procedure.

2. **Mentorship and proctorship:** Mentoring and proctorship play a crucial role in the learning process of AECD. Experienced surgeons can serve as mentors and provide guidance, supervision, and feedback to novice surgeons. Proctorship involves the presence of an experienced surgeon during the initial AECD procedures performed by a trainee, ensuring patient safety and assisting in challenging cases.

3. **Continuing medical education (CME):** Ongoing education and participation in CME programs are essential for surgeons to stay updated with the latest advancements in AECD and related techniques. CME activities, such as conferences, workshops, and online courses, provide opportunities to learn from experts, exchange knowledge, and enhance technical skills.

4. **Surgical simulation:** The use of surgical simulation platforms and virtual reality technology can aid in the training and education of AECD. Simulators allow surgeons to practice and refine their skills in a controlled environment before performing actual surgeries. These platforms can provide realistic anatomical models, haptic feedback, and interactive scenarios to simulate various surgical scenarios encountered in AECD.

5. **Collaboration and peer learning:** Collaboration among surgeons, multidisciplinary team members, and professional societies promotes peer learning and knowledge sharing. Surgeons can attend conferences, join professional societies, and participate in research and case discussions to exchange experiences, discuss challenging cases, and learn from each other's expertise.

6. **Clinical guidelines and consensus statements:** The development of clinical guidelines and consensus statements by expert panels and professional societies helps standardize the indications, techniques, and postoperative care in AECD. These guidelines serve as valuable resources for surgeons in their training and clinical practice, ensuring safe and effective outcomes.

**Recommendations for future research and clinical practice:**

Based on the current understanding of AECD in the management of cervical disc herniation, the following recommendations can be made for future research and clinical practice:

1. **Comparative studies:** Conduct more comparative studies that directly compare AECD with traditional open surgical approaches, as well as other minimally invasive techniques such as microdiscectomy or cervical disc arthroplasty. These studies should evaluate outcomes such as pain relief, functional improvement, complication rates, patient satisfaction, and cost-effectiveness. Comparative studies can provide valuable insights into the relative effectiveness and safety of AECD compared to other treatment options.

2. **Long-term follow-up:** Perform long-term follow-up studies to assess the durability of outcomes after AECD. Investigate the long-term success rates, recurrence rates, and complications associated with AECD over an extended period. Long-term follow-up data will provide a better understanding of the sustained benefits and potential complications associated with AECD.

3. **Standardization of outcome measures:** Establish standardized outcome measures to evaluate the effectiveness of AECD consistently across different studies. Consensus on outcome measures will facilitate meaningful comparisons and meta-analyses of the available data, leading to more robust evidence-based conclusions.

4. **Patient selection criteria:** Refine and standardize the patient selection criteria for AECD. Identify specific patient characteristics, anatomical variations, and clinical presentations that are most suitable for AECD. This will help in optimizing patient selection, ensuring better outcomes, and avoiding unnecessary procedures in patients who may not benefit from AECD.

5. **Training and education:** Continue to focus on training and education for surgeons interested in adopting AECD. Develop standardized training programs, including hands-on workshops, surgical simulation, and mentorship opportunities, to enhance surgical skills and ensure safe and effective adoption of AECD. Additionally, promote the exchange of knowledge and experiences among surgeons through conferences, professional societies, and multidisciplinary collaborations.

6. **Cost-effectiveness studies:** Conduct more cost-effectiveness studies to assess the economic impact of AECD compared to other treatment modalities. Evaluate direct costs, indirect costs, and quality of life outcomes to provide a comprehensive understanding of the economic value of AECD. This information can guide decision-making by healthcare providers and policymakers.

7. **Advances in endoscopic technology:** Continue to explore and develop advancements in endoscopic technology to further improve visualization, instrumentation, and surgical techniques in AECD. Investigate new tools, imaging modalities, and navigation systems that can enhance the safety and efficacy of AECD.

8. **Patient-reported outcomes:** Include patient-reported outcome measures in research and clinical practice to assess the impact of AECD on patients' quality of life, functional status, and satisfaction. Incorporating patient perspectives will provide a more comprehensive understanding of the outcomes and benefits of AECD.

**Summary of key findings:**

- AECD is a minimally invasive surgical technique used for the treatment of cervical disc herniation. It involves accessing the affected disc through a small incision in the front of the neck, using specialized endoscopic instruments and visualization systems.
- The evolution of surgical techniques for cervical disc herniation has led to the development of minimally invasive approaches like AECD. These techniques aim to achieve comparable outcomes to traditional open surgery while minimizing tissue trauma and promoting faster recovery.
- Indications for AECD include cervical disc herniation causing radiculopathy or myelopathy, unresponsive to conservative treatment. Other indications may include foraminal stenosis, discogenic neck pain, and recurrent disc herniation after previous surgery.
- Patient selection criteria for AECD depends on factors such as the location and type of disc herniation, patient's symptoms, and overall health. Factors like the absence of severe instability, presence of intact disc height, and good bone quality are considered when determining the suitability of a patient for AECD.
- The surgical technique of AECD involves various steps, including preoperative planning, patient positioning, access route selection, portal placement, disc space preparation, discectomy, and potential fusion. These steps are performed using specialized endoscopic instruments and visualization systems.
- Clinical outcomes of AECD have shown favorable results in terms of pain relief and functional improvement. Studies have reported significant reductions in neck and arm pain, improvement in neurological function, and high patient satisfaction rates following AECD.
- Rates of neurological recovery after AECD have been promising, with most patients experiencing improvement or resolution of neurological symptoms. The decompression achieved through AECD allows for the relief of neural compression, leading to neurological recovery.
- AECD has demonstrated favorable return-to-work rates and improvements in quality of life measures. Patients who undergo AECD generally experience shorter hospital stays, reduced postoperative pain, and faster recovery compared to traditional open surgery.
- When compared to open surgical approaches, AECD has shown comparable or even superior outcomes in terms of pain relief, functional improvement, complication rates, and patient satisfaction. AECD offers advantages such as reduced blood loss, decreased tissue trauma, shorter recovery time, and improved cosmetic outcomes.
- Cost-effectiveness considerations suggest that AECD can be a cost-effective treatment option due to shorter hospital stays, decreased need for postoperative care, and faster return to work.
- Advances in endoscopic technology have contributed to enhanced visualization and instrumentation in AECD. Techniques such as the use of tubular retractors, microendoscopic approaches, and specialized endoscopic systems have improved surgical precision and outcomes.

**List of Abbreviations:**
ACDF: Anterior Cervical Discectomy and Fusion
AECD: Anterior Endoscopic Cervical Discectomy
CME: Continuing Medical Education
CT: Computed Tomography
EMG: Electromyography
MRI: Magnetic Resonance Imaging
OPLL: Ossified Posterior Longitudinal Ligament
PLL: Posterior Longitudinal Ligament
SSEP: Somatosensory Evoked Potentials

**Acknowledgements:** Not applicable.

**Conflicts of interest:** Authors declare no conflicts of interest.

**Funding:** No funding was acquired.

## REFERENCES

1. Fountas KN, Kapsalaki EZ, Nikolakakos LG, et al. Anterior cervical discectomy and fusion associated complications. Spine (Phila Pa 1976). 2007;32(21):2310-2317. doi:10.1097/BRS.0b013e318154c57e
2. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlman HH. Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. J Bone Joint Surg Am. 1999;81(4):519-528. doi:10.2106/00004623-199904000-00009
3. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic anterior decompression versus conventional anterior decompression and fusion in cervical disc herniations. Int

Orthop. 2009;33(6):1677-1682. doi:10.1007/s00264-008-0684-y
4. Hu Y, Lv G, Ren S, Johansen D. Mid- to Long-Term Outcomes of Cervical Disc Arthroplasty versus Anterior Cervical Discectomy and Fusion for Treatment of Symptomatic Cervical Disc Disease: A Systematic Review and Meta-Analysis of Eight Prospective Randomized Controlled Trials. PLoS One. 2016;11(2):e0149312. doi:10.1371/journal.pone.0149312
5. Wen Z, Lu T, Wang Y, Liang H, Gao Z, He X. Anterior Cervical Corpectomy and Fusion and Anterior Cervical Discectomy and Fusion Using Titanium Mesh Cages for Treatment of Degenerative Cervical Pathologies: A Literature Review. Med Sci Monit. 2018;24:6398-6404. doi:10.12659/MSM.910269
6. Kulkarni AG, Hee HT, Wong HK. Solis cage (PEEK) for anterior cervical fusion: preliminary radiological results with emphasis on fusion and subsidence. Spine J. 2007;7(2):205-209. doi:10.1016/j.spinee.2006.03.002
7. Bhatia S, Brooks NP. Posterior endoscopic cervical foraminotomy. Neurosurgery Clinics. 2020 Jan 1;31(1):9-16. doi:10.1016/j.nec.2019.08.001
8. Wang T, Wang H, Liu S, An HD, Liu H, Ding WY. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in multilevel cervical spondylotic myelopathy: a meta-analysis. Medicine. 2016 Dec 1;95(49):e5437. doi:10.1097/MD.0000000000005437
9. Phillips FM, Allen TR, Regan JJ, et al. Cervical disc replacement in patients with and without previous adjacent level fusion surgery: a prospective study. Spine (Phila Pa 1976). 2009;34(6):556-565. doi:10.1097/BRS.0b013e31819b061c
10. Ahn Y. Anterior Endoscopic Cervical Discectomy: Surgical Technique and Literature Review. Neurospine. 2023;20(1):11-18. doi:10.14245/ns.2346118.059
11. Parihar VS, Yadav N, Ratre S, Dubey A, Yadav YR. Endoscopic Anterior Approach for Cervical Disc Disease (Disc Preserving Surgery). World Neurosurg. 2018;115:e599-e609. doi:10.1016/j.wneu.2018.04.107
12. Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int. 2003;11:255-263.
13. Ruetten S, Komp M, Merk H, Godolias G. A new full-endoscopic technique for cervical posterior foraminotomy in the treatment of lateral disc herniations using 6.9-mm endoscopes: prospective 2-year results of 87 patients. Minim Invasive Neurosurg. 2007;50(4):219-226. doi:10.1055/s-2007-985860
14. Ahn Y. The Current State of Cervical Endoscopic Spine Surgery: an Updated Literature Review and Technical Considerations. Expert Rev Med Devices. 2020;17(12):1285-1292. doi:10.1080/17434440.2020.1853523
15. Ratre S, Yadav YR, Swamy MN, Parihar V, Bajaj J. Endoscopic Anterior Cervical Discectomy (Disc Preserving). Neurol India. 2020;68(6):1310-1312. doi:10.4103/0028-3886.304078
16. Quillo-Olvera J, Lin GX, Kim JS. Percutaneous endoscopic cervical discectomy: a technical review. Ann Transl Med. 2018;6(6):100. doi:10.21037/atm.2018.02.09
17. Ju CI, Kim P, Seo JH, Kim SW, Lee SM. Complications of Cervical Endoscopic Spinal Surgery: A Systematic Review and Narrative Analysis. World Neurosurg. 2023;178:330-339. doi:10.1016/j.wneu.2023.07.058
18. Tsalimas G, Evangelopoulos DS, Benetos IS, Pneumaticos S. Dysphagia as a Postoperative Complication of Anterior Cervical Discectomy and Fusion. Cureus. 2022;14(7):e26888. Published 2022 Jul 15. doi:10.7759/cureus.26888