Neurospine 2024;21(4):1119-1125.
https://doi.org/10.14245/ns.2448796.398

Neurospine
pISSN 2586-6583 eISSN 2586-6591

Video Article

Corresponding Author
Christian Morgenstern
https://orcid.org/0000-0003-4533-4867

Morgenstern Institute of Spine, Centro Médico Teknon, Barcelona, Spain
Email: info@morgenstern.es

Received: August 6, 2024
Revised: October 1, 2024
Accepted: October 9, 2024

Full-Endoscopic Anterior Cervical Decompression and Fusion for Cervical Myelopathy

Christian Morgenstern

Morgenstern Institute of Spine, Centro Médico Teknon, Barcelona, Spain

This article aims to introduce a novel full-endoscopic anterior cervical discectomy and fusion (ACDF) procedure to treat cervical myelopathy. Adoption of endoscopic anterior cervical procedures has been lagging due to safety concerns and the necessity of placing an interbody cage. We have developed novel instrumentation and a modified percutaneous anterior cervical approach that allows a safe and reproducible full-endoscopic ACDF. Specially designed retractor blades facilitate percutaneous placement of a zero-profile cervical interbody cage. A 64-year-old male patient presents with chronic neck pain and bilateral paresthesia in his upper extremities, mild ataxia, and positive Hoffmann sign. He has a history of deep vein thrombosis 5 years prior. Preoperative magnetic resonance imaging and computed tomography scans show a degenerated disk, severe central canal stenosis with cord compression and a hyperintense cord signal at C5–6, compatible with cervical myelopathy. An electromyography of upper extrimities shows suspicion of myelopathy at C5–6. Full-endoscopic ACDF was performed at C5–6 to decompress the canal and restore disk height with a zero-profile interbody cage. Postoperatively the patient showed improvement of his symptoms with reduced pain and disability scores and was discharged from the hospital within 24 hours of the surgery. Outcome is satisfactory at 2-year postoperative follow-up. Full-endoscopic ACDF enables excellent visualization of the posterior endplates and cervical canal with constant irrigation, facilitating treatment of cervical myelopathy. No retraction is required during discectomy and decompression, decreasing the risk of postoperative dysphagia, hoarseness and bleeding. A zero-profile interbody cage can be percutaneously placed with special retractor blades.

Keywords: Endoscopy, Diskectomy, Spinal fusion, Spinal cord compression, Arthrodesis

INTRODUCTION

Endoscopic surgery of the cervical spine has experienced a dichotomous evolution in the last decade: on one side, endoscopic posterior cervical foraminotomy has seen a wide-spread adoption, reporting favorable clinical results for solving cervical foraminal herniations and cervical foraminal stenosis.[1] Recently, indications of the endoscopic posterior approach have been expanded to address central canal stenosis and cervical myelopathy.

In contrast, adoption of the endoscopic anterior cervical approach has been lagging. Full-endoscopic anterior cervical discectomy (eACD) offers advantages like an excellent view of the posterior endplates and the spinal canal thanks to continuous irrigation, decreased pressure on surrounding soft tissues as no retractor is required during discectomy, and a decreased risk of postoperative bleeding and iatrogenic instability thanks to the ultraminimally invasive nature of endoscopy.[1-4] However, eACD currently lacks the possibility to place a cervical interbody cage once full-endoscopic discectomy has been completed. Moreover, one of the main concerns with the endoscopic/percutaneous anterior cervical approach is that it is considered dangerous, as there is no open tissue dissection allowing direct visualization and identification of the trachea, esophagus and the main blood

vessels of the neck (i.e., carotid artery, jugular vein, etc.), presenting risk of a catastrophic vascular injury.

Meanwhile, open ACDF is considered safe and is a well established surgical procedure. Even though it requires dissection of the platysma, it is considered a minimally invasive approach given blunt soft tissue dissection, while allowing clear identification of vascular structures. Nonetheless, also the open anterior cervical approach presents known limitations:

(1) A retractor is usually required over prolonged time to manipulate soft tissue and expose the cervical spine, increasing the risk of postoperative dysphagia, odynophagia, hoarseness and even iatrogenic aphonia due to injury of the (recurrent) laryngeal nerve. In fact, postoperative dysphagia is one of the main reported complications after open ACDF. Studies report an incidence of 5% to 25% of postoperative dysphagia after ACDF,[5,6] including 19% of cases with persistent postoperative dysphagia[6] and up to 10% with severe dysphagia requiring otolaryngology referral.[5]

(2) Postoperative bleeding is another well-known complication after open ACDF. Due to the risk of rapid development of a life-threating, postoperative hematoma, many hospitals still require patients to be postoperatively monitored in an intensive care unit (ICU) for 24 hours.

It was our aim to overcome the mentioned limitations of current ACDF procedures. For this purpose, we have developed a novel approach instrumentation and have modified the standard eACD technique by introducing additional surgical steps to systematically address and improve on the mentioned safety and reproducibility issues of the anterior endoscopic cervical approach. Furthermore, we describe the possibility to complement the full-endoscopic discectomy with a percutaneous insertion of a cervical interbody cage under fluoroscopic guidance.

We are presenting this novel full-endoscopic ACDF procedure by means of a clinical case.

CASE REPORT

A 64-year-old male patient presents to our practice with persistent chronic neck pain and bilateral paresthesia in his upper extremities after unsuccessful conservative treatment (nonsteroidal anti-inflammatory drugs [NSAIDs], muscle relaxants, etc.). He has a history of deep vein thrombosis 5 years prior that was successfully treated with oral anticoagulation. In the physical examination, the patient presented mild ataxia and a bilateral positive Hoffmann sign (right > left).

Preoperative magnetic resonance imaging (MRI) and computed tomography cans show a degenerated disk with posterior osteophytes, severe central canal stenosis with cord compression and a hyperintense cord signal at C5–6, compatible with cervical myelopathy. Cranial and caudal levels to C5–6 did not show central canal stenosis with significant compression of the spinal cord, respectively. A preoperative electromyography of the upper extremities showed suspicion of myelopathy at levels C5–6.

Given the mentioned clinical symptoms and radiologic findings, it was our assessment that targeting the symptomatic level at C5–6 with an anterior cervical discectomy and fusion (ACDF) should allow to satisfactorily decompress the spinal canal and address his symptoms. As endoscopy provides an excellent view of the posterior endplates and the spinal canal with continuous irrigation (Fig. 1A), an endoscopic ACDF was indicated at C5–6 to achieve anterior decompression, removing the posterior osteophytes and restoring the disk height with a zero-profile interbody cage.

The patient was positioned in supine position on a radiolucent table with the neck in moderate hyperextension. Shoulder traction should be considered to allow full fluoroscopic view of the cervical spine. For all full-endoscopic ACDF (eACDF) procedures, we systematically employ a reinforced endotracheal tube and a nasogastric (NG) tube. This ensures that both trachea and esophagus are visible and traceable under intraoperative fluoroscopy, decreasing the risk of injury during the anterior approach. Perioperative neuromonitoring with evoked sensory and motor potentials was employed during the whole surgical procedure. Novel approach instrumentation (360º cervical set, Unintech GmbH, Düsseldorf, Germany) was employed to safely perform a percutaneous anterior approach to the cervical spine and an eACD. Then, specifically designed retractor blades (Signus GmbH, Alzenau, Germany) were used to percutaneously insert a zero-profile cervical interbody cage under fluoroscopic imaging to complete the eACDF procedure. Please refer to the video and the written transcript for a step-by-step description of the complete eACDF surgical procedure.

In the immediate postoperative follow-up, the patient presented minimal residual bleeding in the Redon drain (Fig. 1B) and did not require transfer to the ICU for postoperative monitoring. He showed improvement of his preoperative symptoms with decreased pain and disability scores. He was mobilized 4 hours after surgery and was discharged from the hospital within 24 hours of the surgery.

A postoperative standing x-ray of the cervical spine in lateral

 https://doi.org/10.14245/ns.2448796.398

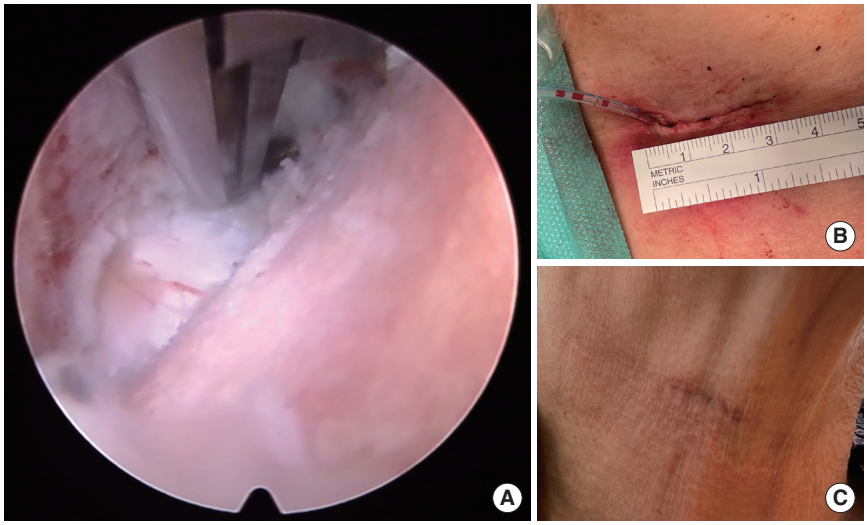

Fig. 1. Intraoperative endoscopic view (A) of the dura and posterior endplates after completing full-endoscopic anterior decompression of the spinal canal immediate postoperative image (B) of the surgical wound of approximately 2.5-cm length with an inlaying Redon drain after full-endoscopic anterior cervical decompression and fusion (eACDF) surgery postoperative image (C) of the surgical wound 12 months after eACDF surgery.

and anterior/posterior views showed a correctly placed interbody cage at C5–6 (Fig. 2). A postoperative MRI at 1-year follow-up showed satisfactory decompression of the operated level at C5–6 with relief of the cord compression. At 2-year postoperative follow-up, the patient remains asymptomatic (Fig. 1) and no complications have been reported.

The patient agreed in written and verbal form to the publication of this case.

WRITTEN TRANSCRIPT

- **00:00** I am presenting on eACD, decompression and fusion for cervical myelopathy with a newly developed set of instruments that allow a safe and reproducible cervical anterior approach.
- **00:14** The advantages of full-endoscopic anterior discectomy comprise excellent view of posterior endplates and the spinal canal thanks to continuous irrigation and the endoscopic lens being right on top of the surgical field. This allows a safe and fast canal decompression. Furthermore, there is no need for a retractor during discectomy which decreases the pressure on surrounding soft tissues like trachea and esophagus, reducing the risk of postoperative dysphagia and hoarseness. Also the risk of iatrogenic instability and postoperative bleeding is decreased due to the ultraminimally invasive nature of full-endoscopic procedures. This facilitates early postoperative ambulation and hospital discharge.

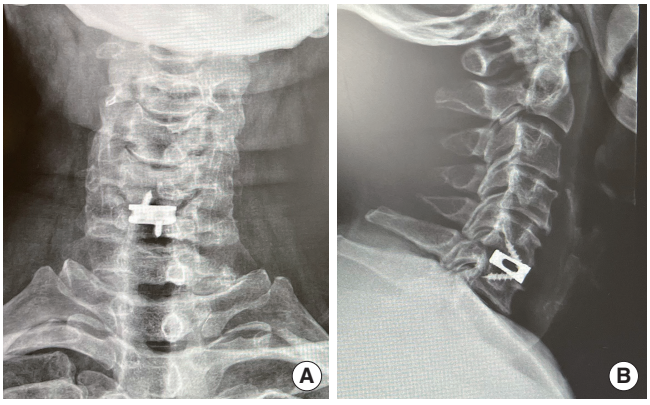

Fig. 2. Postoperative coronal (A) and lateral (B) standing x-ray films of a single-level full-endoscopic endoscopic anterior cervical decompression and fusion.

- **00:57** Case presentation.
- **01:00** This is a 64 year-old male patient with body mass index of 35 kg/m^2, a history of deep vein thrombosis 5 years prior and no other relevant comorbidities.
- **01:11** He presented with chronic neck pain that he was treating with NSAIDs and muscle relaxants, and reported bilateral paresthesia at his upper extremities with a right-sided predominancy. He also reports a feeling of weakness in his lower limbs. Preoperative scores comprise visual analogue scale (VAS) neck of 6 out of 10 , VAS arms 0 and a neck disability index of 25.
- **01:34** In the physical examination we observed a mild atax-

ia with no motor weakness at the upper and lower extremities. Hoffman test was positive, while Babinsky and Lhermitte tests were negative.

- **01:47** Standing and functional preoperative x-rays of the cervical spine were obtained showing no fracture nor apparent instability of the cervical spine.
- **01:56** Preoperative MRI and computed axial tomography scan of the cervical spine showed degenerative disk disease at multiple levels of the cervical spine with a vacuum sign and severe central canal stenosis at C5–6 with a high-intensity sign of the spinal cord at that level compatible with myelopathy. No ossification of the posterior longitudinal ligament was observed.
- **02:15** Levels cranial and caudal to the index level did not present significant cord compression.
- **02:22** eACD and decompression. Surgical technique step-by-step.
- **02:28** The patient was positioned in a supine position on a radiolucent table and underwent general anesthesia. A radiopaque tracheal tube and a NG tube were inserted to intra-operatively locate trachea and esophagus with fluoroscopy. The neck was positioned in moderate hyperextension by placing a cushion roll under the patient's shoulders. Shoulder traction should be considered to allow full view of the cervical spine with intraoperative fluoroscopy. Patients with cervical myelopathy underwent intraoperative neuromonitoring with somatosensory evoked potentials and motor evoked potentials.
- **02:54** After sterile draping use the index and middle fingers of the left hand to push the trachea and esophagus medially, while the carotid artery's pulse should be palpable ipsilaterally. The cervical spine should be clearly palpable at the fingertips atll time. An 18G needle is slid in between the 2 fingertips and inserted into the targeted disk under fluoroscopic lateral control.
- **03:13** The contralateral displacement of trachea and esophagus over the midline should be confirmed with a fluoroscopic image in anterior-posterior (AP) view.
- **03:21** A guide wire is inserted into the disk under fluoroscopic lateral control and the needle is retrieved.
- **03:28** The needle is removed leaving the guide wire in place and a skin incision is done with a knife.
- **03:35** A small, cannulated dilator is gently inserted into the disk guided by the K-wire under fluoroscopic control in lateral and AP views.
- **03:47** To achieve successive soft tissue dilation, a bigger dilator is now introduced over the small dilator until reaching the anterior border of the disk under lateral x-ray view.
- **03:58** Finally, the endoscopic sleeve is placed over the big dilator until reaching the anterior border of the disk. The sleeve will be protecting all surrounding tissues, including trachea, carotid artery and esophagus during the discectomy.
- **04:09** The big dilator is now removed while the small dilator remains in place. This allows inserting the endoscope under guidance of the small dilator, reducing the risk of slipping away from the target disk. This marks the end of the anterior cervical approach as endoscopic view is now established.
- **04:24** An annulotomy is now performed with a crown reamer under direct endoscopic view. In most of the other reported endoscopic anterior techniques[1-4] the annulotomy has been usually performed percutaneously, without having a direct view on the anatomy, which increases the risk of possible complications. Here, the annulotomy is performed under direct sight, while all surrounding tissues are protected by the endoscopic sleeve. This should significantly minimize the risk of a possible injury or complication.
- **04:52** Once the annulotomy has been confirmed, the crown reamer and small dilator are removed, and the endoscopic discectomy can begin. The annulotomy is a critical visual anatomic landmark once the small dilator is removed.
- **05:03** Soft tissues are removed with a forceps and a radiofrequency probe until the disk is exposed. Then, the initial annulotomy is widened with Kerrison punches and scissors.
- **05:17** The anterior endplates and the nucleus are now exposed.
- **05:21** If necessary, anterior osteophytes can be removed with a forceps and a high-speed burr. Nucleotomy is performed with forceps and Kerrison punches until exposing the posterior endplates.
- **05:37** The posterior annulus is gently removed with 1- and 2-mm Kerrison punches. Endplate preparation can be performed with a sharp spoon, Kerrison punches and a high-speed burr, if necessary.
- **05:59** Posterior osteophytes reaching into the canal can be removed with Kerrison punches under fluroscopic lateral control.
- **06:07** Once the posterior longitudinal ligament is clearly visible, decompression with Kerrison punches can begin until the dura is exposed.
- **06:17** The dura should be carefully decompressed until it is fully exposed and decompression is satisfactory. Care should

 https://doi.org/10.14245/ns.2448796.398

be taken not to push on the dura. Irrigation pressure needs to be adjusted accordingly. Bilateral foraminotomies can be performed with Kerrison punches according to usual technique. Note the clear endoscopic view of the dura thanks to the continuous irrigation and the endoscopic lens placed directly on top of it.

- **06:46** Final view of the dura should show a completely decompressed canal with a pulsating dura as a direct and an indirect sign of liberation.
- **06:57** Percutaneous anterior cervical interbody fusion.
- **07:02** Once the full-endoscopic decompression has been completed, the endoscope is removed and the big dilator is reintroduced into the disk. The endoscopic sleeve can now be removed. Specially designed retractor blades are slid on the big dilator until reaching the anterior cervical disk and a retractor is attached to them. Once the retractor is in place and secured, the dilator is removed, and a self-locking cervical interbody cage can be placed under fluoroscopic control.
- **08:06** Finally, a 6-mm Redon drain is placed and subcutaneous tissue and skin are closed with an intradermal suture.
- **08:22** Postoperatively, a stay in an ICU is usually not required. The first ambulation occurs at 4 to 6 hours after surgery and hospital discharge is usually in less than 24 hours. The patient presented with minimal postoperative bleeding with less than 5-mL secretion in the drain. The patient did not present postoperative dysphagia and hoarseness. He reported minimal postoperative pain with VAS neck = 2, VAS arm = 0 and neck disability index of 24. No opioid medication was require dduring postoperative follow-up.
- **08:58** At 24-month postoperative follow-up, the patient reports clear improvement of preoperative clinical symptoms with postoperative scores of VAS neck = 2, VAS arm = 0 and neck disability index of 15 with no need for pain medication.
- **09:14** Preliminary results presented here were obtained by one surgeon in one center. They need to be confirmed by a randomized controlled trial with a high sample size and control cohorts. Endoscopic ACDF presents several limitations: the anterior endoscopic approach should not be performed in patients with vascular anomalies of the neck, thyroid hyperplasia and/or struma, tumor of the neck and relevant esophageal and/or tracheal pathology. It is also of limited use in cases of revision surgery and cervical deformity that need a wider skin incision to place a plate and bigger implants.

DISCUSSION

In this clinical case presentation, we have introduced a newly developed approach instrumentation and a modified endoscopic/percutaneous anterior cervical approach for full-endoscopic ACDF. The advantages of eACDF comprise excellent view of posterior endplates and the spinal canal thanks to continuous irrigation and the lens being right on top of the surgical field (Fig. 1), allowing a safe and efficient canal decompression.[1-4] Furthermore, there is no need for a retractor during discectomy which decreases the pressure on surrounding soft tissues like trachea and esophagus, which should reduce the risk of postoperative dysphagia and hoarseness.[1-4] Also the risk of iatrogenic instability and postoperative bleeding is decreased due to the ultraminimally invasive nature of full-endoscopic procedures, facilitating early postoperative ambulation and hospital discharge.[1-4] The novel instrumentation and modified surgical steps introduced here allow increasing the safety and reproducibility of the endoscopic/percutaneous cervical anterior approach, while the specifically developed retractor blades allow complementing the full-endoscopic ACD with the insertion of a zero-profile cervical interbody cage (Fig. 2). Some of the key aspects of this novel eACDF procedure in comparison to previously described techniques are discussed in the following:

1) A reinforced endotracheal tube and a NG tube is systematically employed for all eACDF patients. This ensures that both trachea and esophagus are traceable under intraoperative fluoroscopy, see video at 03:13, decreasing the risk of injury during the approach. Hence, general anesthesia is recommended for an eACDF procedure.
2) Endoscopic (i.e., lumbar, thoracic, and cervical) procedures are based on the concept of progressive soft tissue dilation. Blunt dilators with progressively increasing diameter, like the ones employed in this eACDF procedure, avoid damaging soft tissue during the endoscopic approach. Additionally, also the bevel of the sleeve is blunt and the adjustment with its corresponding dilator is usually in the range of approximately 0.5 mm. Hence, the risk of a possible soft tissue damage by the sleeve is minimal if the approach is performed correctly. The percutaneous interbody cage placement relies on the same principle, as specially designed blades adjust on a dilator to allow soft tissue retraction and exposing the prepared disk for cage insertion under fluoroscopic guidance.
3) During the anterior approach, initial docking of the endoscope can be challenging as the endoscope can slip from

the target level and orientation can be lost. When this happens, the surgeon is usually compelled to removing the endoscope and restarting the cervical anterior approach to the target level from anew. In order to avoiding this, here, the initial docking of the endoscope is performed using a guiding dilator that is anchored into the disk. This minimizes the probability of the endoscope slipping from the target.

4) The initial annulotomy with a crown reamer is a critical step during the endoscopic anterior cervical approach. We consider it a main improvement of our endoscopic ACDF technique that the annulotomy is performed under direct endoscopic view, the crown reamer is firmly guided by a dilator anchored to the disk and surrounding soft tissue is protected by the endoscopic sleeve. These 3 measures considerably reduce the risk of an incidental soft tissue injury during the anterior approach.
5) The annulotomy creates a main anatomic landmark that allows visually locating the entrance to the disk space once the guiding dilator has been removed. In the case that the endoscope slips and/or if orientation is lost, the surgeon can visually locate the entry point to the disk using this anatomic landmark and resume the discectomy without having to restart the complete approach from anew. Hence, a proper initial annulotomy is critical to save surgical time and avoiding to restart the anterior cervical approach from anew (with all corresponding risks). These measures represent an improvement over previously described techniques that relied on a percutaneous annulotomy with a crown reamer without endoscopic visualization and soft tissue protection by a sleeve.[2-4]
6) Visualization can be impaired if irrigation can not properly enter an extremely collapsed disk.
   (1) An increase in irrigation pressure can, but may not necessarily improve visualization. As a rule-of-thumb, irrigation pressure should usually be kept under diastolic pressure.[7,8] However, once the cervical dura has been exposed, it is recommended to decrease irrigation pressure as much as possible as long as visualization is ensured. In our institution, we avoid using an irrigation pump and only use gravity for endoscopic cervical spine procedures. In our experience, gravity allows an optimal visualization in most cases, while limiting irrigation pressure below potentially critical pressure values. Irrigation temperature needs also to be considered and serum temperature should be kept close to body temperature.
   (2) One of the most important measures to improve visualization for collapsed disks is distracting the disk to allow optimal access for the irrigation into the disk. Anterior bone spurs and osteophytes can be removed with the high-speed burr and Kerrison punches, like in open ACDF. Disk distraction can be achieved by progressively introducing endoscopic dilators into the disk. In a last step, even the endoscope itself could be introduced into the disk, if necessary. Precaution should be taken especially in osteoporotic bone, as introducing the endoscope into a collapsed and osteoporotic disk space could cause a fracture of the vertebral body. Distracting the disk height progressively with dilators is a critical step to ensure a safe distraction and avoiding fractures.
   (3) Usually, a 10º endoscopic scope angle suffices for an optimal visualization of the disk during eACDF.
   (4) We have observed soft tissue edema related to irrigation fluid in the surrounding soft tissues of the neck after an anterior cervical endoscopy. The edema usually resolves within the first postoperative hour. In our opinion, it does not cause pressure on the trachea and it does not delay extubation time. Hence, in our experience, irrigation-related post-opeartive soft tissue edema does not have any clinical consequence for the patient.

Despite all described improvements, endoscopic ACDF still presents with limitations: the anterior endoscopic approach should not be performed in patients with vascular anomalies of the neck, thyroid hyperplasia and/or struma, tumor of the neck, relevant esophageal and/or tracheal pathology, etc. It is also of limited/relative use in cases of revision surgery, fracture and cervical deformity that require a wide skin incision and extensive retraction of the cervical spine to place large implants and plates. For these cases, a mini-open anterior cervical approach with blunt finger dissection or a standard open approach could be alternatively considered to perform an eACDF.

In conclusion, full-endoscopic ACDF allows excellent visualization of the posterior endplates and cervical canal with constant irrigation, opening the possibility to treat cervical myelopathy. As no retraction of soft tissues is required during discectomy, the risk of developing postoperative dysphagia, hoarseness and bleeding is decreased. Furthermore, an interbody cage can be percutaneously placed with specially designed retractor blades under fluoroscopic guidance. We believe that this video case presentation provides educational value by presenting a step-by-step description of a novel eACDF technique on a challenging case of cervical myelopathy.

 https://doi.org/10.14245/ns.2448796.398

Considering the mentioned limitations, we believe that this novel eACDF technique is a safe and reproducible procedure that could help increase the attractiveness and adoption of percutaneous/endoscopic anterior cervical procedures. Nevertheless, a randomized controlled trial with multiple arms comparing ACDF to eACDF each with a large cohort, respectively, is recommended to analyze and compare the potential benefits and limitations of each surgical technique.

NOTES

Video File: The video file for this article is available at https://doi.org/10.14245/ns.2448796.398.

Conflict of Interest: Christian Morgenstern reports consulting and royalty fees by Maxmore Spine GmbH, Signus GmbH, and Unintech GmbH. Consulting fees by Spineart SA. Except for that, the author has nothing to disclose.

Funding/Support: This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgments: The author would like to thank Dr. Rudolf Morgenstern and Geoffrey Delbos for their support.

Author Contribution: Christian Morgenstern is the single author of this article.

ORCID

Christian Morgenstern: 0000-0003-4533-4867

REFERENCES

1. Alomar SA, Maghrabi Y, Baeesa SS, et al. Outcome of anterior and posterior endoscopic procedures for cervical radiculopathy due to degenerative disk disease: a systematic review and meta-analysis. Global Spine J 2022;12:1546-60.
2. Ruetten S, Komp M, Merk H, et al. Full-endoscopic anterior decompression versus conventional anterior decompression and fusion in cervical disc herniations. Int Orthop 2009;33:1677-82.
3. Saringer WF, Reddy B, Nobauer-Huhmann I, et al. Endoscopic anterior cervical foraminotomy for unilateral radiculopathy: anatomical morphometric analysis and preliminary clinical experience. J Neurosurg 2003;98:171-80.
4. Choi G, Lee SH, Bhanot A, et al. Modified transcorporeal anterior cervical microforaminotomy for cervical radiculopathy: a technical note and early results. Eur Spine J 2007;16:1387-93.
5. Tasiou A, Giannis T, Brotis AG, et al. Anterior cervical spine surgery-associated complications in a retrospective case-control study. J Spine Surg 2017;3:444-59.
6. Paziuk T, Mazmudar AS, Issa TZ, et al. Does operative level impact dysphagia severity after anterior cervical discectomy and fusion?: a multicenter prospective analysis. Spine (Phila Pa 1976) 2024;49:909-15.
7. Kang T, Park SY, Lee SH, et al. Assessing changes in cervical epidural pressure during biportal endoscopic lumbar discectomy. J Neurosurg Spine 2021;34:196-202.
8. Joh JY, Choi G, Kong BJ, et al. Comparative study of neck pain in relation to increase of cervical epidural pressure during percutaneous endoscopic lumbar discectomy. Spine (Phila Pa 1976) 2009;34:2033-8.