Full Endoscopic Anterior Cervical Discectomy and Interbody Fusion in Patients with Cervical Spondylotic Myelopathy

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Abstract

**Background:** For the surgical treatment of cervical spondylotic myelopathy (CSM), anterior decompression with fusion or posterior decompression using microscopy has been used widely as the standard procedure, depending on the location of pathology and the surgeon’s preference. Endoscopic anterior cervical discectomy and interbody fusion (E-ACDF) is a minimally invasive, effective surgical option for the management of CSM. The advantages of using endoscopy for anterior cervical discectomy and interbody fusion (ACDF) are better visualization of the operative field with the possibility of changing the angle of the endoscope. This reduces the damage to the normal anatomical structure. Although long-term follow-up results are needed to evaluate fusion rate and complication, this appears to be a safe and feasible alternative to conventional ACDF for CSM. In this article, we have described the surgical technique, summarized the endoscopic process to discuss its operative strategies, and reviewed the radiographic records, pre- and postoperatively.

**Material and Methods:** This retrospective review study included 36 cases aged 37 to 65 years, with CSM at one segment. All of them underwent full E-ACDF from January 2018 to April 2021. All patients were followed up for 12 months after the procedure by outpatient interviews. The clinical outcomes were evaluated based on the Visual Analog Scale (VAS) of the arm, and Japanese Orthopedic Association (JOA) score with clinical data at preoperative, 3, and 12 months after the operation. Hirabayashi method was used to assess the neurological recovery after 12 months of operation. Radiological outcomes were evaluated using plain radiography and magnetic resonance imaging, computed tomography scan to evaluate disc height, cervical lordosis (Cobb’s angle), and solid fusion.

**Results:** The mean operation time was 150 min (range 120–170 min) and the average length of hospital stay was 2 ± 3 days. There was one case of immediate postoperative anterior neck hematoma, which required open revision surgery. There was no case of infection or damage to the anterior visceral organ. The mean VAS scores for arm pain and mean JOA scores after endoscopic ACDF were significantly improved compared with before the operation during the follow-up period. The recovery rate, which was evaluated by the Hirabayashi method, looked good enough to indicate well recovered postoperatively. The disc height changed from 5.2 mm preoperatively to 6.2 mm after immediate postoperative and 5.9 mm after 6 months (*P* < 0.01). Cervical lordosis as Cobb’s angle between C2 and C7 was significantly improved.
INTRODUCTION

Anterior cervical discectomy and interbody fusion (ACDF) are the common place in the surgical management of cervical spine pathologies. Cervical spondylotic myelopathy (CSM) caused by a large amount of spondylosis or ossification of the posterior longitudinal ligament (OPLL) is one of the most common causes of progressive spinal cord dysfunction in the adult population.\(^1,2\) The diagnosis of CSM is based on the symptoms, the presence of myelopathic findings on physical examination, and the correlation between signal change on magnetic resonance imaging (MRI).\(^3\) Operative management is indicated in most patients with CSM because the early operation is beneficial for most patients with advanced myelopathy. Various operative techniques\(^4,5\) are available for patients with CSM. The decision is made based on multiple factors, including the location (ventral or dorsal), size, and the extent of pathology, the sagittal alignment the curvature of the neck (lordosis or kyphosis), how long a patient is in trouble, and how seriously a pathology compresses the spinal cord and patients with myelopathy having a canal diameter of < 12 mm.\(^6\) The anterior approach is used as a standard option to manage a lesion in the ventral part of the spinal cord and extend less than three consecutive segments.\(^7\) In minimally invasive spine surgery (MISS) for degenerative cervical spine diseases, the posterior approach of endoscopic spine surgery has been a matter of interest. Recently, clinical study articles have demonstrated excellent clinical results of posterior foraminotomy and discectomy in the cervical and lumbar spines.\(^8,9\) However, the myelopathy associated with the central disc herniation and ossification of the PLL (OPLL) is difficult to access by the endoscopic posterior approach.

Amid the growing desire and interest in Endoscopic ACDF (E-ACDF), a few reports were reporting an outcome of full endoscopic cervical discectomy without inter-body fusion.\(^12,13\) However, an anterior approach discectomy of cervical endoscopic surgery without fusion might bring about kyphosis at the index segment and axial neck pain postoperatively. Later, a paper on E-ACDF\(^14\) was published, but it was not popularized because the simplification of the method was not established.

In this study, E-ACDF is performed for patients with central disc herniation, calcified disc, one-level localized type OPLL that has a progressive neurological deficit, and debilitating pain that is resistant to conservative treatment with the signal change of spinal cord on MRI.

The purpose of the current study is to demonstrate the process of full E-ACDF in detail to share the authors’ experiences of the surgical techniques and to find out its feasibility.

MATERIALS AND METHODS

Patients and clinical assessment

The purpose of E-ACDF is to achieve the effective decompression of the spinal canal and bone fusion for the maintenance of stability with the less invasive and precise surgical technique. In the present study, the authors performed full E-ACDFs for CSM with one level central disc herniation, calcified disc, and localized OPLL who suffered from a progressive neurological deficit. The patient should have debilitating pain that was resistant to conservative treatments and presented signal changes of the relevant spinal cord at a single segment on MRI.

This study was conducted at Good Doctor Teun Teun Hospital, Anyang, and Seoul Segyero Hospital, Seoul, South Korea, the study protocol was approved by the Institutional Review Board of the Hospital. This retrospective study was done through a review of hospital records of 36 consecutive patients who had been diagnosed with one level CSM [Table 1].

Conclusions: The present study demonstrates that E-ACDF is a minimally invasive and effective surgical option for the surgical management of CSM. Based on the present study, E-ACDF may potentially enable the avoidance of various shortcomings related to surgical approaches. Through a sort of preliminary investigation, the authors confirmed the feasibility of E-ACDF and presented comparable outcome results, which might dispel the safety concern because of only one complication of wound hematoma. Better-designed randomized controlled studies with larger sample sizes in longer-term follow-ups are strongly warranted.

Keywords: Anterior cervical discectomy and fusion, cervical spondylotic myelopathy, endoscopic spine surgery, stenoscope
All of them underwent full E-ACDF from January 2018 to April 2021. All patients were followed up for 12 months after the procedure by outpatient interviews. The demographics, mean age, gender, operation time, length of hospital stay, and complications were recorded through a review of medical records. MRIs were done within 24 h postoperatively for all patients to demonstrate any complications.

The clinical outcomes were evaluated based on the Visual Analog Scale (VAS) of the arm, and Japanese Orthopedic Association (JOA) Score with clinical data at preoperative, 3, and 12 months after the operation. The Hirabayashi method was used to assess the neurological recovery after 12 months of operation.

**Radiographic assessment**

For radiologic evaluation, plain radiographs, and computed tomography (CT) scan was performed preoperatively and then postoperatively at 3 and 12 months. MRI was done within 24 h postoperatively for all patients to demonstrate the immediate postoperative complications. The radiological parameters including the change in disc height, global cervical lordosis, and fusion rate were measured. The authors assessed radiologic outcomes by measuring the disc height, cervical lordosis, and solid fusion.

The disc height was defined as the distance from the midpoint perpendicular to the endplate line of the vertebral body at the fusion disc level. Plain lateral radiographs on pre and post-operative 3 and 12 months were used to calculate disc height and solid fusion. Cobb angle between C2 and C7 after E-ACDF was reviewed to evaluate cervical lordosis. The C2–C7 Cobb angle is defined as the Cobb angle between C2 and C7 cervical inferior endplate on standing lateral cervical X-rays in the neutral position [Figure 1].

Fusion status was defined as a lack of instability between the vertebral bodies on flexion and extension radiographs, no cage migration, and the presence of bony bridging of index level through the intervertebral space or around the cage on a lateral plain radiograph at 12 months postoperatively. An additional evaluation was done by CT, in case of any suspicion regarding the union [Figure 2].

**Surgical technique**

The purpose of E-ACDF is to achieve effective decompression of the spinal canal and bone fusion for CSM with less invasive and precise surgical procedures. The operation is performed utilizing general anesthesia, supine position with the neck slightly extended. Both shoulders are gently pulled caudally using leukoplast. Insertion of a radiographically visible Levin tube helps know the exact location of the esophagus during procedures.

An ipsilateral anterior approach to the symptomatic side, between the medial border of the common carotid artery and the lateral border of the thyroid, is recommended. The surgical area is cleaned with an antiseptic solution and a sterile drape is placed over the anterior neck. The surgical level to be operated on was confirmed with an anteroposterior and lateral view by C-arm radiography.

Using the left index and middle finger, firmly pressing the anterior neck to separate the thyroid and trachea, esophagus from the pulsatile carotid sheath, to make sufficient working space for endoscopic procedures, until the anterior disc to be treated was touched. The surgeon passes a thin needle through the space between two fingers into the midline of the disc space gently after confirming the correct placement of the needle at the surgical level using a C-arm. Then, a 15-mm transverse skin incision deep to the platysma was made around the thin needle to allow the passage of serial working dilators (2 mm ~ 13 mm outer diameter serial dilator) [Figure 3].

The 9.5 mm outer diameter working sleeve was then inserted into the 15 mm skin incision. The working sleeve should be placed in the midline between both longus colli muscles and should not advance over the contralateral longus colli muscle on C-arm AP view to prevent injury of the esophagus [Figure 4].

The endoscope is inserted into the surgical site through the working sleeve. The endoscopic system should remain upright and perpendicular to the disc space, to allow the surgeon to identify the operative field. It could play a key role in preventing damage to the anterior cervical visceral structures [Figure 5].

A tiny space between the 15 mm skin incision and a 9.5 mm working sleeve will help the discharge of the irrigation

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**Table 1: Patients demographics**

<table>
<thead>
<tr>
<th>Demographic variables</th>
<th>N=36</th>
</tr>
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<tbody>
<tr>
<td>Number of patients</td>
<td>36</td>
</tr>
<tr>
<td>Mean age (years) (range)</td>
<td>56.2 (37-65)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17</td>
</tr>
<tr>
<td>Female</td>
<td>19</td>
</tr>
<tr>
<td>Clinical diagnosis</td>
<td></td>
</tr>
<tr>
<td>Radiculopathy</td>
<td>10</td>
</tr>
<tr>
<td>Myelopathy</td>
<td>26</td>
</tr>
<tr>
<td>Level implanted</td>
<td></td>
</tr>
<tr>
<td>C34: n=4, C45: n=6, C56:</td>
<td></td>
</tr>
<tr>
<td>n=13, C67: n=10, C7T1: n=3</td>
<td></td>
</tr>
<tr>
<td>Mean operation time (min)</td>
<td>150±12.06</td>
</tr>
<tr>
<td>Mean hospital stay (days)</td>
<td>2±03</td>
</tr>
</tbody>
</table>
water outside and because only a small water amount seeps into the muscles and soft tissues, there is less swelling of the surrounding tissues after surgery.

In terms of endoscopic equipment, we performed endoscopy for ACDF using an 8 mm outer diameter, 5.5 mm working channel, 10° angled lens spinal endoscopic system (Stenoscope, MaxMore Spine Company, Unterföhring, Germany)\(^\text{18}\) which is composed of the light conductor system, a canal for continuous irrigation and the 5.5 mm working channel, which allows the passage of a Kerrison punch (1–5 mm), high-speed diamond bur (2, 3 mm) and 4 mm cage holder [Figure 6].

All the endoscopic procedures were performed with continuous 0.9% saline solution irrigation containing epinephrine for hemostasis, which secures clear visualization. Using high-resolution endoscopy and continuous water
irrigation, the surgeon can see prevertebral anatomical structures in more detail and clearly during the procedure with less bleeding. The first step in the process is to open the prevertebral fascia at the surgical level using a steerable radio frequency (RF) device, to make enough safe zone on the anterior annulus surface of the vertebral body to be removed [Figure 7a].

Ablation of the medial portion of the ipsilateral longus colli muscle by RF is essential to expose the medial parts of the uncovertebral joint, which is to be removed at the end stage of the procedure. Once the medial portions of the longus colli have been exposed, the ipsilateral uncovertebral joint can be seen easily and resection is more comfortable.

The second step in the process is removing the annulus by using RF and a 2 mm Kerrison punch, between the ipsilateral with contralateral longus colli muscle. And then careful discectomy and removal of the endplate cartilage can be carried out by using the 2mm forceps, Kerrison punch, and drill [Figure 7b and c].

Disc and posterolateral osteophytes, PLL as well as the uncovertebral joint were removed to decompress the spinal cord and underlying root fully in the 3rd step [Figure 7d]. It is necessary to proceed cautiously with drilling at the base of the uncinate process because the nerve root lies just adjacent to it.

During the endoscopic procedures, the device for opening the disc space, the vertebral distractor was not used. When decortication and detaching the endplate cartilage using a 3 mm high-speed burr and angled curette, to make an adequate fusion bed and to enlarge the disc space to secure an adequate working space, careful attention is given not to violate the endplates.

The removal of posterior osteophyte and PLL should be careful. The Kerrison punch should not be inserted too deeply into the epidural space to prevent spinal cord injury [Figure 7e, and f]. After enough decompression of disc space and uncovertebral joint, dura pulsation is observed under the endoscopic view [Figure 7g and h].

To insert the fusion cage under the endoscopic view, we used two smooth-tipped retractor systems [Figure 8] through a 1.5 cm skin incision. It allowed inspection of the relevant anatomical structure while providing sufficient space for implantation with safety, also allowing drainage of irrigation water and blood at the final stage, which would cause soft tissue swelling, postoperatively.

In the fourth stage, the procedure of implanting a PEEK cage is similar to that of conventional open cervical surgery. The disc height was determined by the proof [Figure 9a]. The cage was selected at a 1mm larger size than the measurement to increase the disc height. The cage is filled with DBM (Demineralized Bone Matrix) before implantation [Figure 9b]. To insert the cage into the disc space, 4 mm of the cage holder was introduced into the 5.5 mm endoscopic working channel to hold the chosen PEEK cage.

The implantation process involves holding the ends of the cage, and insertion of the implant into the surgical field under the endoscopic visualization [Figure 9c and d]. C-arm is then used to confirm the appropriate position and alignment of the cage. In all cases, only the stand-alone cage was used without plate fixation.
In the final stage, bleeding was controlled in the prevertebral space by using bipolar cautery. A suction drain was placed under the endoscopic view, and its position was confirmed by C-arm. These steps are essential to prevent postoperative hematoma [Figure 10]. The fascia and skin were closed after the working sleeve was removed.

The suction drain was taken off on the next postoperative day, based on the total amount of drainage measured and confirmation of postoperative MRI. The patients were discharged within the next 2 days after surgery.

All patients needed to wear the Philadelphia brace for at least 4 weeks after surgery.

**RESULTS**

All patients had a statistically significant reduction in VAS score for radicular pain in the arm at the first 3 months and 12 months in comparison to the preoperative score \( (P < 0.01) \). The mean JOA score significantly improved from a preoperative score of \( 10.5 \pm 8.6 \) to \( 14.2 \pm 1.5 \) at 3 months and \( 17.2 \pm 2.1 \) at 12 month postoperatively \( (P < 0.01) \) at the last follow-up. The recovery rate calculated by Hirabayashi's method after 12 months of surgery was \( 63\% \pm 21.0\% \) [Table 2 and Figure 11].

The disc height was significantly improved from \( 5.3 \pm 6.9 \text{ mm} \) preoperatively to \( 6.0 \pm 5.4 \text{ mm} \) at 3 months and \( 5.8 \pm 4.9 \text{ mm} \) at 12 months postoperatively \( (P < 0.05) \). Disc height tended to decline after 3 months, but all showed solid fusion and did not lead to definite subsidence, or foraminal symptoms [Table 3 and Figure 12]. Few authors have reported no clear correlation\[16\] between disc height changes and clinical efficacy within a year of surgery.

The outcomes of the cervical Cobb angle show a significantly improve from \( 10.6^\circ \pm 5.9^\circ \), preoperatively, to \( 11.2^\circ \pm 4.2^\circ \) at 3 months and \( 11.7^\circ \pm 5.7^\circ \) at 12 months after operation \( (P > 0.05) \) [Table 3 and Figure 12]. A fusion rate that was confirmed by X-ray and CT scans was observed in all 36 cases (100%) at 12 months. No implant complications were observed in all patients during the follow-up period.

**DISCUSSION**

CSM is one of the most frequent reasons for adults’ spinal cord dysfunction. Various surgical options exist for CSM management, including both anterior and posterior approaches. The goals of operative management are to decompress the spinal cord, minimize surgery-induced injury of the surrounding soft tissues, and stabilize the spine. Over the past decades, MISS for CSM has been...
evolving and is currently being employed to address CSM through the anterior and posterior approaches.\textsuperscript{[17]}

Technological advances have allowed endoscopic posterior decompression in which the surgeon can have a clear surgical view with the endoscope, which has been getting popular for cervical foraminal stenosis, paracentral disc herniation, and spinal canal stenosis. The endoscopic posterior approach for decompression has several advantages\textsuperscript{[18]} due to its minimally invasive nature. It includes reduced intraoperative bleeding, hospital stay duration, and postoperative axial pain, and can preserve posterior ligament complex that maintains stability and causes less postoperative axial neck pain, consequently enabling a patient to recover and return to the workplace faster.

In surgery for myelopathy associated with anterior pathologies like central huge disc herniation, or calcified

Table 2: Clinical results of endoscopic anterior cervical discectomy and interbody fusion using Visual Analog Scale and Japanese Orthopedic Association score

<table>
<thead>
<tr>
<th>Clinical outcomes</th>
<th>Mean±SD</th>
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<tbody>
<tr>
<td>VAS</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>6.6±0.9</td>
</tr>
<tr>
<td>Postoperative (months)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3.6±2.9</td>
</tr>
<tr>
<td>12</td>
<td>2.4±1.1</td>
</tr>
<tr>
<td><em>P</em></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>C-JOA score</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.5±8.6</td>
</tr>
<tr>
<td>Postoperative (months)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14.2±1.5</td>
</tr>
<tr>
<td>12</td>
<td>17.2±2.1</td>
</tr>
<tr>
<td><em>P</em></td>
<td>&lt;0.01</td>
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VAS: Visual Analog Scale, JOA: Japanese Orthopedic Association

Table 3: Disc height and cervical lordosis

<table>
<thead>
<tr>
<th>Radiologic parameter</th>
<th>Mean±SD</th>
</tr>
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<tbody>
<tr>
<td>Disc height</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>5.3±6.9</td>
</tr>
<tr>
<td>Postoperative (months)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6.0±5.4</td>
</tr>
<tr>
<td>12</td>
<td>5.8±4.9</td>
</tr>
<tr>
<td><em>P</em></td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Cervical lordosis</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.6±5.9</td>
</tr>
<tr>
<td>Postoperative (months)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>11.2±4.2</td>
</tr>
<tr>
<td>12</td>
<td>11.7±5.7</td>
</tr>
<tr>
<td><em>P</em></td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
disc and OPLL, posterior endoscopic access is difficult. So trans-anterior surgery should be chosen. The goal of E-ACDF in cervical myelopathy is to achieve appropriate decompression with efficient interbody fusion and to avoid collateral injury to nearby anatomical structures and related complications. The development of endoscopic systems has brought about the improvement of the resolution and clearness of endoscopy, and a surgeon can now explore the intradiscal and spinal canal anatomy in detail.

Also using continuous water irrigation during procedures provides the surgeon with a clearer operative field and the ability to get the endoscope close to the pathology, normal anatomy, and a less bloody surgical view. It reduces surrounding organ damage and surgical infection also. As a result, an operated patient can minimize pain medication and antibiotics usage, early recovery followed by a rapid return to the workplace, and high satisfaction. Ruetten et al.\(^\text{[13]}\) in their comparison study between the full endoscopic simple discectomy and conventional ACDF, reported comparable clinical results between the groups while obtaining endoscopic surgical benefits in the former.

According to the results of the present study, clinical trial with full E-ACDF achieved excellent postoperative clinical outcomes, not only improving postoperative VAS score and JOA score and recovery rate, as assessed by Hirabayashi’s method, but also improved radiological outcomes including an increase of disc height, Cobb’s angle and a reasonable fusion rate.

Endoscopic spine surgeons may expect that E-ACDF would have the merit of endoscopic surgery and the familiarity of conventional ACDF surgical technique. It is because endoscopy allows passage of the surgical instrument and fusion devices such as 1 ~ 5mm of the Kerrison punches, grasping forceps, dissectors, a radiofrequency coagulator, and a high-speed drill like open surgery. The operation view of endoscopy is like that of open surgery, and all procedural steps may be familiar to the surgeon who has experience with microscopic ACDF surgery.

The disadvantage of E-ACDF is unable to use the distractor to make space between the upper and lower bodies to put a graft cage. So it is necessary to have a long-term follow-up to know the postoperative graft-related complications, including displacement, subsidence of graft, migration, adjacent segment disease, and pseudoarthrosis.

The authors have experienced one case of surgery-related complication, limited to superficial hematoma at the very beginning of this trial. The patient needed revision surgery to remove the hematoma. Up to 5.6% of postoperative hematomas\(^\text{[19]}\) are comparable to those reported in other published papers. Bleeding from the surgical site may obstruct vision and should be dealt with aggressively. The authors additionally applied other countermeasures against bleeding during ESS as follows. Firstly, decreasing blood pressure (BP) (down to 30%-40% of mean BP) and maintaining it during the procedure, and secondly, increasing the pumping pressure of continuous saline irrigation (up to 60 mmHg).

This retrospective study demonstrates the feasibility of ACDF for CSM using endoscopy and could replace the conventional open ACDF if the learning curve could be overcome. To show more information on the E-ACDF procedure for those with the proper indications, two cases are presented.

**Case 1**
A 46-year-old male with radicular pain in the right C5 dermatome and weakness in both arms with C5-6 level myelopathy. Preoperative MRI and CT scan show C5-6 myelopathy and calcified disc at C5-6 [Figure 13]. The calcified disc and hypertrophic posterior osteophyte can be removed to decompress the spinal canal. The PLL can be removed to confirm the dural pulsations.
Endoscopic surgery has relatively little bleeding, a clear operative field, and safe surgery can be carried out. The postoperative MRI and CT scan show increased spinal canal area and the correct placement of the cervical cage [Figure 14].

Case 2
The 2nd patient reviewed was a 37-year-old male with symptoms of significant radicular pain in the left arm and upper extremity weakness. MRI demonstrated a signal change in the spinal cord at the C4-5 level and disc herniation on the left side at the same level [Figure 15a and b]. Postoperative MRI showed a marked increase in spinal canal size compared with preoperative size [Figure 15c and d]. Postoperative CT scan showed effective decompression of cervical lesion and endoscopic surgery [Figure 16].

CONCLUSIONS
The E-ACDF is one of the minimally invasive procedures using spinal endoscopy that allows safe and effective clinical outcomes for the surgical management of CSM. The 8.0 mm endoscope provides advantages including good visualization due to the high resolution of endoscopy, less bleeding during the operation, and less soft-tissue swelling postoperatively.
This new E-ACDF technique has shown excellent clinical outcomes with adequate anatomical decompression and good result of fusion rate in patients with CSM so it may be considered an alternative method to the traditional open ACDF for CSM. Well-designed randomized control trials are required to develop instruments for safety and effectiveness as well as confer potential advantages in the surgical trends of the future.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES