Microsurgical Anterior Cervical Foraminotomy for the Treatment of Unilateral Cervical Radiculopathy; Clinical and Radiological Outcomes

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ABSTRACT

Object: *The study was aiming at comparing ACF which is a cervical motion preserving technique with the more conventional cervical discectomy and fusion (ACDF) for the same indication (unilateral cervical radiculopathy).* ***Methods:*** *Thirty patients with unilateral cervical radiculopathy who had failed conservative treatment for at least 6 weeks were randomly assigned to one of two groups of 15 patients and treated at Ain Shams University Hospitals by either anterior cervical foraminotomy (ACF) or anterior cervical discectomy and fusion (ACDF) (using autologous bone graft or cervical cage). There were 15 patients in each group that had similar demographic and clinical features. Disc herniations and/or uncovertebral osteophytes were confirmed on CT scan and MRI.* ***Results:*** *In accordance with Odom's criteria excellent or good results were achieved in the ACF group during a mean follow-up period of 11.5 months. A poor result was observed in only one patient, that had an unresolved radicular pain that required repeat surgery in the form of ACDF for a missed osteophyte at the operated level. The overall subjective patient satisfaction rate with this surgical procedure was 91.7% . Thirteen of the patients (86.7%) returned to work or their baseline level of activity within 3 weeks postoperatively. The above results and outcomes for the ACF procedure are favorable and comparable with the ACDF group. In accordance with Odom's criteria, excellent or good results were achieved in the ACDF series during a mean follow-up period of 15.4 months. A poor result was not observed. The overall subjective patient satisfaction rate with this surgical procedure was 96.7%. Thirteen of the patients (86.7%) returned to work or their baseline level of activity within 6 weeks postoperatively.*
Conclusion: *The advantages of ACF include direct decompression of the nerve root, and the preservation of the intervertebral disc and motion segment with favorable results comparable to those achieved by the conventional ACDF .Thus ACF can be used as an alternative technique in selected cases.*

Key words: Cervical radiculopathy, Anterior discectomy, Anterior foraminotomy.

INTRODUCTION

Cervical radiculopathy from intervertebral disc herniation was originally described by *Mixter and Barr in 1934*[15], and the treatment has evolved steadily since that.

The initial surgical management was a posterior laminectomy or a small keyhole foraminotomy approach that provided exposure of the nerve root that may include removal of a nonvisualised disc herniation or osteophytes by curettage ventral to the nerve. This was the only treatment for many years. It had the advantage of preserving the spinal motion segment and has been reported extensively to have good success[10].

The difficulty of an indirect posterior exposure and inability to remove some ventral lesions led to the current and more common use of anterior discectomy procedures first described by *Robinson and Smith in 1955 and Cloward in 1958*[4]. These represented a significant technical advance that provided surgeons with the direct access to lesions most often located ventral to the exiting nerve. Fusion of the interspace provided immobilization of potentially painful

degenerative disc and facet joints and justified a more extensive nerve decompression procedure.

Alternatively, discectomy without fusion has also been performed with similar favorable results, but most of these patients may actually have fusion in the surgically treated segment[9]. Unfortunately, bony fusion of a motion segment in the highly mobile cervical spine may result in further progression of degenerative changes at other disc levels eventually requiring further surgery. *Hilbrand,et al,in1997*[11], postulated that up to 25% of the patients who undergo cervical fusion could require treatment of adjacent level disease within 10 years.

An ideal operation for cervical disc herniation must fulfill two requirements: It must completely eliminate the offending disc disease whether soft disc or bone spur, thus allowing direct nerve root decompression; and it must preserve motion in the surgically treated segment[1].

This can be accomplished with the anterior cervical foraminotomy procedure that was refined by *Jho HD in 1996*[12], after previous similar reports in the literature dating to 1968[8].

The aim of this study is to assess the clinical and radiological outcomes for the anterior cervical foraminotomy procedure, in the treatment of patients with unilateral radiculopathy, comparing it with the more conventional anterior cervical discectomy and fusion.

PATIENTS & METHODS

This prospepective study was done on thirty patients with unilateral cervical radiculopathy treated at Ain Shams University Hospitals. The patients were randomly assigned to one of *two groups of 15 patients* and treated by either an anterior cervical foraminotomy (ACF) or anterior cervical discectomy and fusion (ACDF). The patients were evaluated over a period of 2 years.

Inclusion criteria for this study is as follows:

- Unilateral cervical radiculopathy that had not responded to conservative treatment for more than 6 weeks.
- Imaging studies confirming pathoanatomic features (posterolateral disc herniation or osteophte compression) corresponding to the clinical symptoms.
- No previous cervical spine surgery.
- No significant spondylotic stenosis causing spinal cord compromise.

Exclusion criteria for this study is as follows:

- Cervical mylopathy.
- Imaging studies showing central or paracentral stenosis, deformity or instability.
- Previous cervical spine surgery.

Preoperative assessment:

Preoperative assessment included thorough clinical assessment (including general and neurological examination). All patients completed study forms including questions regarding work and daily function, as well as the 10 point visual analogue scale (VAS) rating the extent of pain[19]. Routine preoperative investigations together with radiological investigations confirming pathoanatomic features corresponding to the clinical symptoms were done (Including plain X-ray, CT and MRI of the cervical spine.).

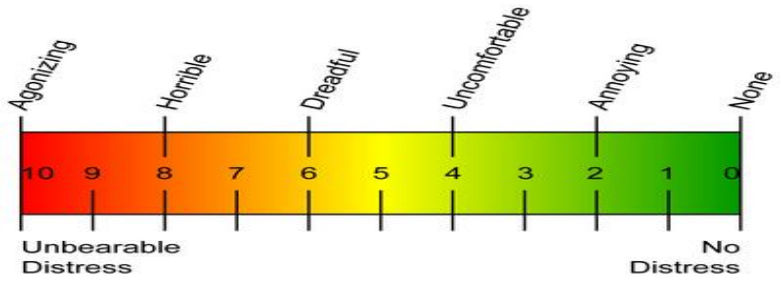


FIG. 1: The 10 point visual analogue scale (VAS) Wewers & Lowe[19].

Surgical procedures:

I- Anterior Cervical Foraminotomy (ACF):

The detailed surgical technique has been reported by *Jho et al.* [13].

Anesthetic considerations and Patient positioning:

After induction of general anesthesia with endotracheal intubation, the patient is placed supine with the head in a neutral position.

Skin incision and soft tissue dissection:

A transverse skin incision is made ipsilateral to the lesion. The platysma is divided along the line of the incision, and the dissection is deepened using both sharp and blunt dissection in the plane between the carotid sheath laterally and the tracheoesophageal structures medially.

The prevertebral fascia is opened, and the correct level is confirmed using a lateral fluoroscopic imaging.

The ipsilateral longus colli is stripped laterally to expose the medial half of the transverse process above and below the disc space. The vertebral artery is not exposed.

The contralateral longus colli is dissected from the vertebral body approximately 2 to 3 mm laterally (just enough for insertion of a self-retaining retractor blade beneath it). The teeth of the self-retaining retractor blades are then placed beneath the dissected longus colli muscles. The anesthetist is asked to deflate the endotracheal balloon, and then reinflate it at a lower pressure, allowing the balloon to move away from the retractor blade. (This helps to avoid indirect injury to the recurrent laryngeal nerve by stretching or pressure).

Identification of bony entry site on the anterior aspect of the cervical spine and bone drilling:

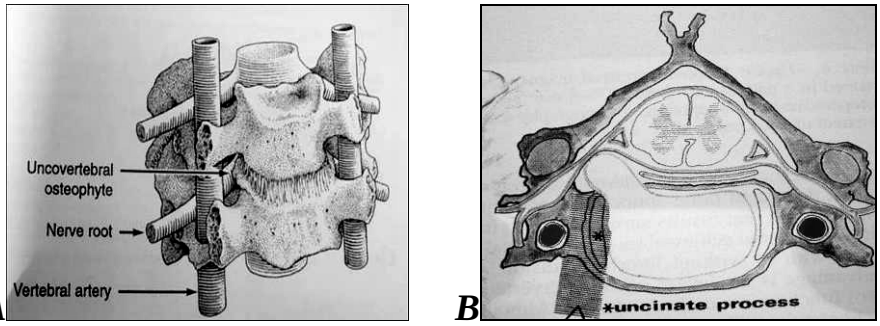
An upper vertebral transcorporeal approach involves starting drilling at the most lateral, inferior 4-5 mm portion of the upper-level vertebral body of the intervertebral disc and the medial 1 or 2 mm portion of the transverse foramen (The anterior portion of the uncinate process is not removed).

A lower vertebreal transcorporeal approach involves starting drilling at the base of the uncinate process of the lower-level vertebra of the intervertebral disc.

The entry point on the anterior aspect of the spine must be customized on the basis of the three-dimensional orientation of the pathological lesion and the surgical trajectory.

A 2 mm cutting drill bit is used. The drilling bit is changed to a diamond drill as one advance. The cartilaginous endplate of the upper-level vertebral body is exposed but not entered in the anterior two-thirds of the foraminotomy tract.

The transverse diameter of the hole is approximately 7-8mm, and the vertical diameter of the hole varies with the height of the disc spaces in different vertebral levels (approximately 10mm).



A ***B***

FIG. 2: Diagrams illustrating the ACF

A- *The relationship between the uncovertebral osteophyte, the exiting cervical nerve root, and the vertebral artery illustrated (Grundy P.L et al, 2000) (7).*

B- *Artistic illustration of the approach showing the direction of drilling towards the compressive protruded disc (Tascioglu A.O, et al, 2001) (18).*

Exiting root decompression: (removal of compressive uncovertebral osteophytes and / or protruded disc)

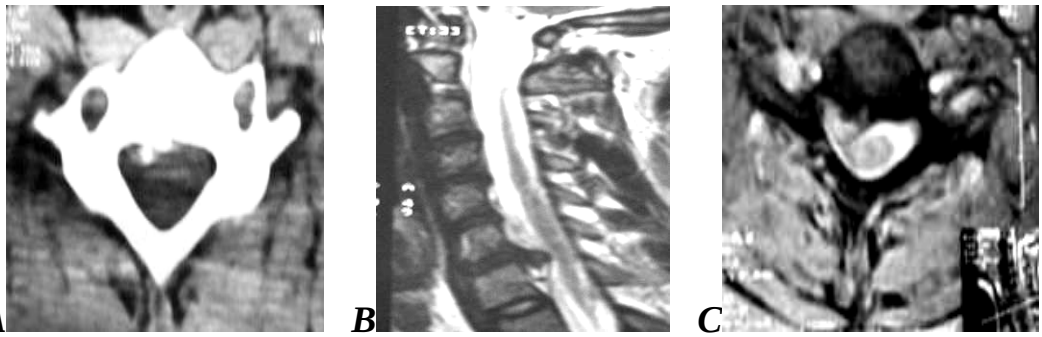
At the posterior one-third of the foraminotomy hole, the uncovertebral junction is entered and the posterior portion of the lateral uncinate process, which often represents the pathological element compressing the nerve root, is removed. The rostral and caudal lips of the posterior uncovertebral juncture are thus removed. Final removal of the compressive uncovertebral osteophytes is done using a 1 mm foot plate Kerrison.

Identification of the lateral border of the posterior longitudinal ligament (PLL) shows that the posterior border of the uncinate process is reached. Since the PLL partly covers the proximal parts of the nerve roots, its lateral border must be excised, preferably using a microhook and a 1 mm foot plate Kerrison to expose the lateral border of the ipsilateral spinal cord. The root can then be exposed from its origin to its entrance into the neural foramen. If there is no ruptured herniated disc fragment behind the PLL, this will be the end of the nerve root decompression.

The disc within the intervertebral space remains untouched and preserved.

Closure:

After copious wound irrigation, the walls of the wound are checked for any bleeding, which is then controlled. The platysma layer is closed with interrupted 3-0 Vicryl suture and the skin is closed with a running subcuticular 4-0 Vicryl suture. The suture line is reinforced with Steri-Strips. A neck collar is not used.



A ***B*** ***C***

FIG. 3: CT axial cut (A) and MRI sagittal (B) and axial (C) cuts at C6-7 level, show disc osteophyte complex compressing the exiting right C-7 nerve root.

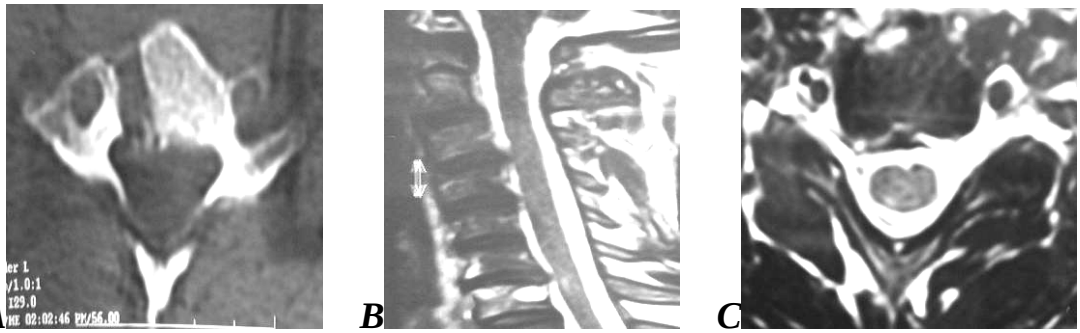


FIG. 4: CT axial cut (A) and MRI sagittal (B) and axial (C) cuts at C6-7 level, showing complete removal of the disc osteophyte complex via lower vertebral transcorporeal approach.

II-Anterior Cervical Discectomy and Fusion (ACDF):

Surgical procedures were carried out using the common anterolateral approach according to Smith-Robinson via a right-sided skin incision. The posterior longitudinal ligament was excised thoroughly to ensure adequate neural decompression. Gentle decortication of the endplates was performed with a drill or curette. Interbody fusion is achieved using an autologous bone graft or cervical cage. Postoperatively, all patients wore a hard neck collar for approximately 6 weeks.

Postoperative assessment:

I. Clinical outcome:

Especially noting radicular pain (assessed using the 10-point visual analogue scale)[19], sensory disturbance and motor weakness compared with the pre-operative status.

Functional outcome was assessed according to Odom's criteria[16]. It was defined as:

1. Excellent in patients who had no complaints referable to cervical disc disease and were able to carry on their daily routines without any impairment.
2. Good outcome was defined as intermittent discomfort related to cervical disc disease which, however, did not significantly interfere with work.
3. Satisfactory outcome was defined as subjective improvement but limited physical activities.
4. Poor outcome included patients who did not improve or worsened after surgery.

To evaluate patient satisfaction with postoperative results, a patient satisfaction index (PSI) was applied. This index is a modified subitem of the North American Spine Society outcome questionnaire[5]. It is scored as follows:

1- Very satisfied (surgery met my expectations)
2- Satisfied (I did not improve as much as hoped but would undergo the same operation for the same results.)
3- Unsatisfied (surgery helped but I would not undergo the same operation for the same results)
4- Very unsatisfied (I am the same or worse than before surgery)

II. Radiological outcome: (done within 6 weeks after surgery and at follow-up as necessary) included:

- Plain X-rays of the cervical spine: (A-P, lateral (neutral, flexion/extension) and right /left oblique views)

ACF group: for evaluation of cervical spine alignment, disc height, bony entry site, evidence of maintained cervical motion at operated level and

for excluding any post-operative cervical spine instability. (Spinal instability was quantified by an increased intervertebral angle difference in flexion-extension of more than 12˚ or displacement of the vertebral body over 3.5mm in flexion.)[20]

ACDF group: for evaluation of cervical spine alignment, position of the implant and follow-up of fusion. (A segment was deemed fused if there was less than 2˚of segmental movement on lateral flexion-extension views, if less than 50% of the anteroposterior distance of the interface between the endplates and implant was radiolucent, and if the interspinous distance did not change more than 2 mm.[2])

- MRI or CT of the cervical spine :

ACF group: routinely performed within 6 weeks of surgery mainly for assessment of the degree of neural decompression.

ACDF group: MRI of the cervical spine was performed only when there was clinical evidence of persistent or recurrent symptoms.

All patients were *followed at regular intervals (1 month, 3 months, 6 months, and 1 year)* including a clinical and radiological evaluation (as explained above).

RESULTS

Clinical Demographics:

ACF group:

Patients ranged from 37 to 59 years of age, with a mean age of 44.5 years. The male-to-female ratio was 1:2, with 5 men and 10 women. The patient's clinical presentations were categorized into five primary categories: neck pain, radiculopathy, decreased sensation, decreased motor strength and altered reflexes. Of the 15 patients 6 (40%) had significant neck pain. Fifteen (100%) reported classic radiculopathy. Eight (53.3%) had decreased or altered sensation. Six (40%) had some level of diminished strength, with 5 (33.3%) also having accompanying reflex changes. The mean duration of symptoms was 13 months.

ACDF group:

Patients ranged from 38 to 49 years of age, with a mean age of 41.7 years. The male-female ratio was 0.88:1, with 7 men and 8 women. The patient's clinical presentations were categorized into five primary categories as above. Of the 15 patients 8 (53.3%) had significant neck pain .Fifteen (100%) reported classic radiculopathy. Nine (60%) had decreased or altered sensation. Five (33.3%) had some level of diminished strength, with 5 (33.3%) also having accompanying reflex changes. The mean duration of symptoms was 15 months

Pre-operative Radiographic Characteristics:

ACF group:

4 patients had compressive soft disc fragments, 7 had foraminal osteophytes, 4 patients had a disc-osteophyte complex.The operated levels are summarized in *Fig. 4.*

ACDF group:

3 patients had compressive soft disc fragment, 4 had foraminal osteophytes, and 8 patients had a disc-osteophyte complex. The operated levels are summarized in *Fig. 4.*

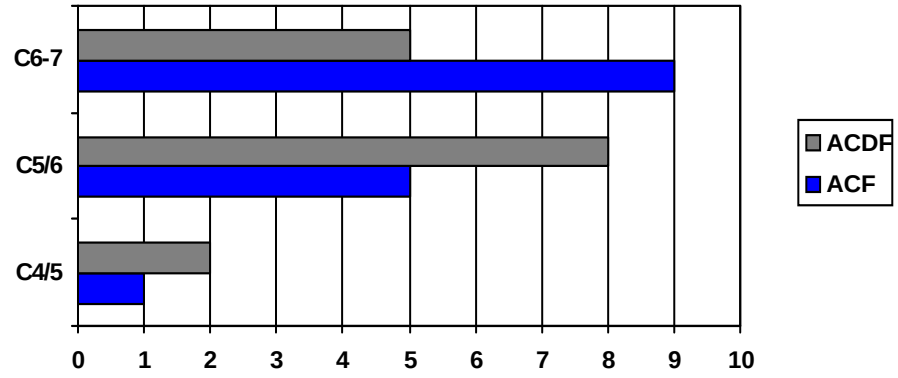


Fig. 5: A bar graph showing the anatomic distribution of the operated-on levels and number of patients in each of the ACF and ACDF groups

Operative Data:

ACF group:

The side of surgery was dictated by the side of radiculopathy. The side of surgery and technique of ACF used are summarized in *table 1.* Operative time ranged from 115 minutes to 150 minutes (earlier cases taking the longer time); mean operative time was 125 minutes.

ACDF group:

All cases were done via a right-side approach regardless of the side of radiculopathy. The type of material used for interbody fusion and number of patients is summarized in *table 1.* Operative time ranged from 90 minutes to 120 minutes (cage fusion taking less time than an autologous iliac crest bone graft); mean operative time was 110 minutes.

Table 1: Surgery related variables in both the ACF and ACDF patient groups.

Surgery related variables	Number
ACF:	
I)Side of approach	
-Right	11
-Left	4
II) Technique of ACF	
-Upper vertebral transcorporeal approach	6
-Lower vertebral transcorporeal approach	9
III)Mean operative time (minutes)	125
ACDF:	
I)Type of fusion	
-Autologous iliac crest bone graft	7
-Cage fusion:- PEEK cage	7
-Carbon cage	1
II)Mean operative time (minutes)	110

Operative Complications:

ACF group:

None of the patients experienced permanent surgery-related morbidity. One patient sustained a palsy of the ipsilateral recurrent laryngeal nerve, which resolved spontaneously within 6 weeks. There was no case of Horner's syndrome in this series. There were no wound related problems. No relapse of radicular pain occurred in any patient during the follow-up period. Only one patient (early in this series) with an unresolved radiculopathy (due to an incomplete osteophyte removal) had to undergo repeat surgery in the form of ACDF.

ACDF group:

None of the patients experienced permanent surgery-related morbidity. None of the cases experienced recurrent laryngeal nerve injury or Horner's syndrome. However, one case of dysphagia was observed that resolved in 2 weeks. There were no wound related problems. There was however a significant number [6 (85.7%)] of the autologous iliac crest graft patients that had a persistant graft site pain that remained persistant during all follow-up visits. The mean VAS score of the graft site pain was 3/10.This was not evident in the cage fusion patients in whom graft site pain resolved in a mean duration of 3 months.

Postoperative Outcome:

I-Clinical Outcome (resolution of pain and recovery of neurological function)

Clinical outcomes regarding the three cervical symptom clusters (neck pain, radicular pain, and neurological deficits) at time of hospital discharge, at 1 month, 3 months, 6 months and 1 year are summarized in *Fig. 5* The outcome was assessed objectively by an improvement in the VAS scores, patient satisfaction and the absence of the need for analgesics.

It was noted that radicular pain improved immediately in both surgical groups. Motor deficit took a longer time and needed physiotherapy. Reflex changes remained unchanged in a significant number of patients with a motor weakness. Sensory changes improved in a significant number of patients in both groups.

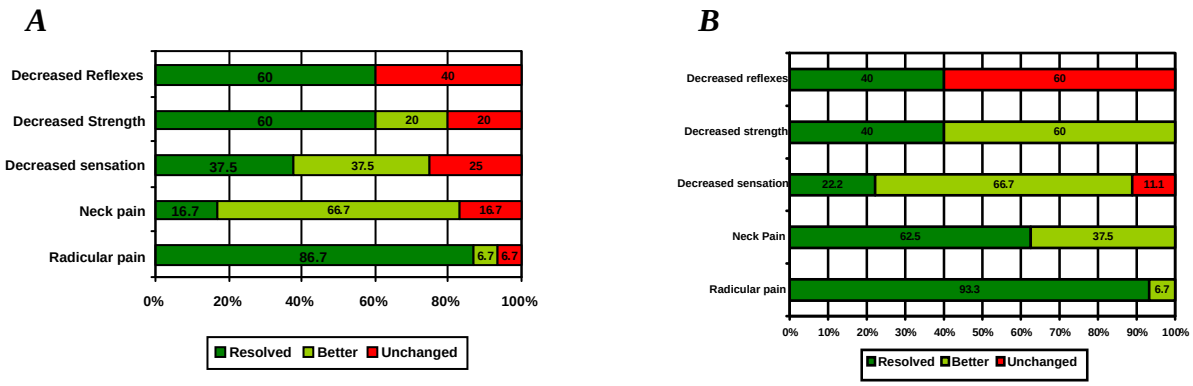


FIG. 6: Graphs summarizing the outcome by symptom and sign

***A**-In ACF surgical group*

***B**-In ACDF surgical group*

II-Functional Outcome:

The functional outcome (assessment of work incapacity and Odom's criteria is illustrated in *Fig. 6* and the postoperative patient satisfaction is illustrated in *Fig. 7).*

ACF group:

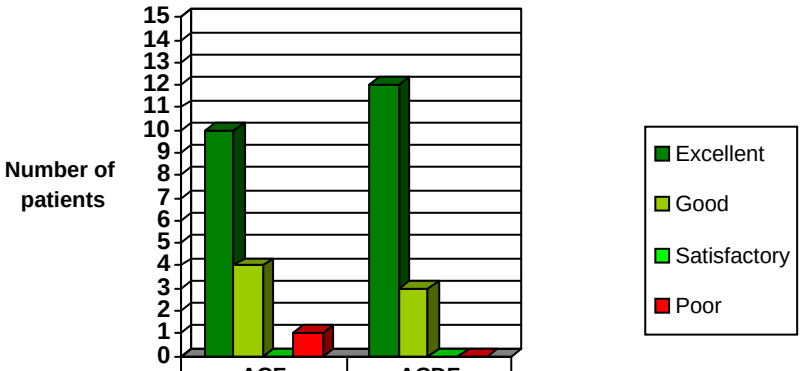
In accordance with Odom's criteria excellent (10 (66.7%) patients) or good (4 (26.7%) patients) results were achieved in this series during a mean follow-up period of 11.5 months. A poor result was observed in only one patient (6.7%), that had an unresolved radicular pain, that required repeat surgery in the form of ACDF for a missed osteophyte at the operated level.

The overall subjective patient satisfaction rate with this surgical procedure was 91.7%. Thirteen of the patients (86.7%) returned to work or their baseline level of activity within 3 weeks postoperatively.

ACDF group:

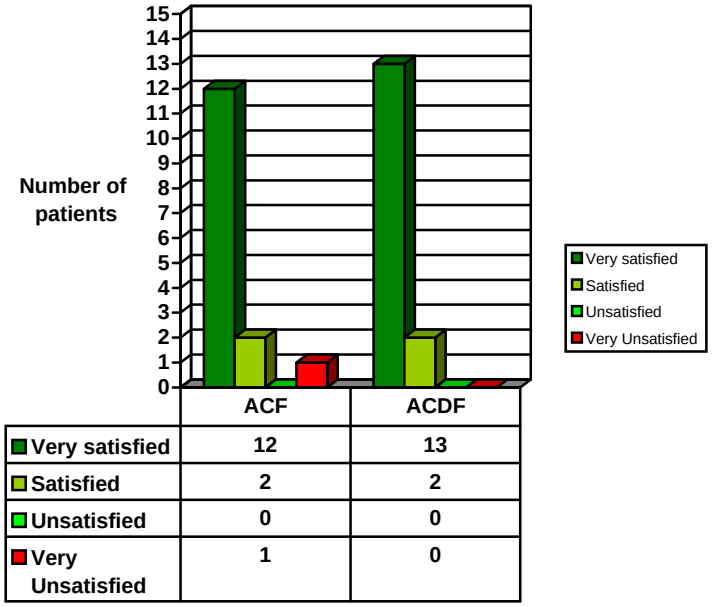
In accordance with Odom's criteria excellent (in 13 (86.7%) patients) or good (in 2 (13.3%) patients) results were achieved in this series during a mean follow-up period of 15.4 months. A poor result was not observed.

The overall subjective patient satisfaction rate with this surgical procedure was 96.7%. Thirteen of the patients (86.7%) returned to work or their baseline level of activity within 6 weeks postoperatively.



	ACF	ACDF
Excellent	10	12
Good	4	3
Satisfactory	0	0
Poor	1	0

FIG. 7: Bar graph demonstrating functional outcome evaluated according to Odom's criteria in the ACF and ACDF groups. Both groups entail a similar outcome.



	ACF	ACDF
Very satisfied	12	13
Satisfied	2	2
Unsatisfied	0	0
Very Unsatisfied	1	0

FIG. 8: Bar graph showing postoperative patient satisfaction for the 2 surgical groups.

III-Radiological Outcome:

ACF group:

Neuroimaging follow-up data obtained in all patients:

- Immediate postoperative evaluation: *maintained range of motion* at operated level and no evidence of instability
- MRI done within 6 weeks of surgery: *adequate root decompression* at operated levels in all patients *except* one of the earlier cases (the 2nd case in the ACF surgical series) who clinically had an unchanged VAS score (7/10) for the radicular pain. This patient had a missed osteophyte at the level of surgery and went on to do an ACDF with cage insertion.
- Long term follow-up showed no evidence of delayed instability or a significant reduction of disc height in the surgically treated levels, and maintained range of motion as pre-operative status.

ACDF group:

Neuro-imaging follow-up data was as follows:

- Immediate postoperative evaluation: showed good positioning of the autologous bone graft or cage in all cases; as well as maintenance of disc height and foraminal height.
- Follow-up for fusion and graft-related problems was as follows:

Autologous iliac crest graft subgroup:

Graft collapse was observed in 2 (28.6%) of the autologous iliac crest graft surgical subgroup .Graft collapse did not correspond with any new clinical symptom though a persistence of mild neck pain continued. Radiographically, the degree of graft collapse was unchanged at 12 months compared with 3 months postoperatively. *Graft protrusion* was not observed in any of the cases.

Fusion rate: Successful fusion was observed in 5(71.4%) of the 7 patients at the one year follow-up visit

Cage fusion subgroup:

Cage collapse /subsidence or *protrusion* was not observed in the 8 patients of this subgroup.

Fusion rate: Successful fusion was observed earlier in this subgroup, being complete at 6-9 months in 7 (87.5%) of the 8 patients.

Adjacent segment disease was observed early (at 6 weeks postoperative) in one of the cases, whereby adjacent segment reduction in disc height and localised kyphotic angulation was observed, being manifest clinically by ongoing mild neck pain. Follow-up visit at 6 months postoperative showed that the reduction in height of the higher adjacent segment and kyphotic angulation remained stationary.

DISCUSSION

The benefits of the ACD with fusion allowing direct access to the offending lesion and the complete decompression of the spinal cord and affected nerve roots are well-known. The major disadvantages of the traditional anterior approach are fusion-related complications including graft-related complications, graft-site complications and adjacent-segment disease.

In large well-established series of ACDF, the rates of autograft or allograft related complications, including graft subsidence or graft extrusion with collapse of the disc, pseudoarthrosis, and wound infection are reported to range from 2.3 to 6%. Graft site complications in the case of autografting from the iliac crest, such as wound infection, hematoma, avulsion fracture of the anterior superior iliac spine bone, hernia, injury to the iliohypogastric or ilioinguinal nerve, cosmetic deformity, or persistent pain have been reported to range from 4.9 to 18%[(3)].

Anterior interbody fusion (or ACD without fusion, which subsequently leads to bone fusion in most cases,) results in the loss of a motion segment, leading to increased strain-induced mechanical stress exertion on adjacent segments[(6)]. Radiographic and MRI changes following anterior cervical fusion have been well described as adjacent segment disease. *Gore et al.*[(6)], reported in a clinical and radiographic review of 50 patients who underwent ACDF that there was an accelerated disc degeneration of the adjacent levels requiring further surgery in 16% during a mean follow-up period of 21 years. *Hilbrand et al.*[(11)], postulated that up to 25% of the patients who undergo cervical fusion could require treatment of adjacent-level disease within 10 years.

To avoid this significant accompanying morbidity to ACD, especially in young patients with a long life expectancy after the operation, the functioning motion segment should be preserved during surgery whenever possible. One such technique of cervical motion preservation is the ACF, and we took about this study to investigate the outcome of such technique as compared to a control group treated by the conventional method of ACDF.

In *1996 Jho*[(12)] used an anterolateral approach for unilateral cervical radiculopathy. The concept involved a direct removal of the compressive pathological entity while preserving the motion unit. The 1st reported technique was the "transuncal approach", which we have not used, knowing that such a procedure may cause lateral collapse, frontal-plane tilt and rotary instability. This frontal-plane tilt causes vertical collapse of the neural foramen despite the widened neural foramen on the axial plane. This may result as a result of excessive

removal of the lateral intervertebral anatomy[13].

In this study we have used the upper or lower transcorporeal techniques as described by *Jho et al.*[13]. These modified techniques largely preserve the uncovertebral joint avoiding the above mentioned complications.

The major advantage of anterior microforaminotomy is that it preserves the motion unit anatomically as well as functionally. This was successfully achieve in all of our ACF patients who exhibited mechanical stability and maintained segment motion postoperatively (during the mean follow-up of 11.5 months), as indicated in dynamic cervical X-rays.

The disadvantages are unfamiliarity with the procedure and the long-term issues related to disc degeneration at the operated level and hence possible recurrence of symptoms. Thus long-term follow-up is needed.

The clinical outcomes appear favorable compared with the ACDF group (as illustrated in *Fig.4*and *5* in the results section).This is especially true concerning radicular pain relief (86.7% in ACF group v.s 93.3% total radicular pain relief in the ACDF group).The ACDF procedure has ,however, a better outcome as concerns axial neck pain where 62.5% of ACDF patients had a total relief of neck pain , as opposed to only 16.7% having total neck pain relief in the ACF patient group .This is probably related to the fusion in the ACDF group.

Our clinical outcomes seem to also parallel those of the other reported ACF series[7,13,14,17].

Conclusions

Anterior cervical foraminotomy for cervical radiculopathy is effective in well selected patients. Only patients with unilateral single level radicular syndromes and corresponding neuroimaging–documented postero-lateral disc or osteophytic lesions are the appropriate candidates. It is a minimally invasive technique with which direct resection of an offending lesion can be accomplished with complete decompression of the affected root and preservation of the motion segment .Thus potentially avoiding the long term degenerative changes at adjacent levels. Although longer patient follow-up is required to address issues related to progressive disc degeneration at the operated level and hence possible recurrence of symptoms.

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