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Technical Notes & Surgical Techniques

Anterior cervical fusion versus minimally invasive posterior keyhole decompression for cervical radiculopathy

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ABSTRACT

Background: Treatment modalities for degenerative cervical spine disease are widely debated and refined as new surgical techniques are developed. The current case series compares two common cervical spine procedures, anterior cervical discectomy and fusion (ACDF) and minimally invasive posterior keyhole foraminotomy (MIPKF). The decision making process of the two surgical approaches is discussed, and the long term outcomes are presented.
Methods: A retrospective chart review of surgical patients having either an ACDF or MIPKF with an extensive chart review. Over 570 patient charts were identified and reviewed between 1994 and 2011. After exclusion, a total of 268 patients were identified in the ACDF group, and 112 patients were identified in the MIPKF group. Primary outcome measurement was the need for any reoperation, whether at the same level or adjacent levels due to recurrence of disease or adjacent level disease.
Results: An average follow-up of 11.8 (±3.0) years in the ACDF group and 6.4 (±4.4) years in the MIPKF group was determined over a 17 year period. There was a reoperation rate of 2.6% in the ACDF group and 2.7% in the MIPKF group during the 17 year time period.
Conclusion: ACDF has been demonstrated to be an effective surgical procedure in treating degenerative spine disease in patients with radiculopathy and/or myelopathy. However, in a population with isolated radiculopathy and radiological imaging confirming an anterolateral disc or osteophyte complex, the MIPKF can provide similar results without the associated risks that accompany an anterior cervical spine fusion.
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1. Introduction

Degenerative disease of the cervical spine is a leading cause of neck and arm symptoms. If the pathology is a herniated disk, the disk can be removed and the spinal segment fused in the common anterior cervical discectomy and fusion (ACDF) operation. Alternatively, for a lateral disk herniation with associated radiculopathy, a posterior foraminotomy that decompresses the individual nerve root can be performed.

There is some evidence that a fusion at one cervical disk level subjects the levels above and below to higher forces [1–3], and many surgeons believe that fusion increases the risk for adjacent segment disease. Thus, the foraminotomy procedure potentially reduces the risk of disk herniation at the adjacent levels. In appropriate patients, the foraminotomy would therefore be the preferred surgical procedure given several studies demonstrating that its efficacy is similar to that of an ACDF procedure [4–15].

Further refinements to the foraminotomy procedure have been made with the recent development of commercially available minimally invasive surgery instruments [16–18]. These dilators and tubes allow the muscles to be spread rather than cut, thus preserving more of the natural anatomy of the cervical spine. The senior author has been performing the foraminotomy procedure through a custom made retractor for years prior to the advent of the commercially available sets, giving George Washington University one of the oldest series of minimally invasive posterior keyhole foraminotomies (MIPKF).

Previous series have evaluated the adjacent level disk herniation risk of ACDF procedures [19–26] and foraminotomy procedures [27]. Other studies have compared ACDF to foraminotomy for clinical efficacy outcomes [28–30], but no single series comparing the two procedures for subsequent adjacent level disk herniation and rate of reoperation has been performed. Thus, this study compares the incidence of adjacent level degeneration between patients who received an ACDF and those with a MIPKF performed by the same surgeon at George Washington University over a fifteen-year period.

2. Methods

A retrospective chart review was performed with the approval by the George Washington University Institutional Review Board under IRB protocol# 100724. The retrospective chart review ranged between 1994 and 2011 with the search criteria including patients undergoing an ACDF or

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MIPKF performed by the senior author (A.J.C). A database search was performed using current procedural terminology (CPT) codes: CPT code #22554 was used for ACDF, and CPT code #63020 was used for MIPKF

The chart review detailed each patient's age, surgical indication, level(s) of operation, follow-up dates, and possible reoperation. Exclusion criteria included age less than 18 and inadequate chart information such as lack of operative level, age, MRI reports, or surgical indication(s). Patients who were operated on for traumatic discs, fractures, tumor, infection, or vascular lesions were also excluded from the analysis. Further information such as MRI reports, neurological exams, surgical indications, and types of surgery performed was also obtained. A total of 268 ACDF and 112 MIPKF cases met the inclusion criteria, while 199 cases were excluded.

2.1. Surgical methods

2.1.1. Minimally invasive posterior keyhole foraminotomy

After induction of general anesthesia, large bore IVs are obtained by the anesthesiologist, and placement of a precordial Doppler is used in preparation for the semi-sitting position. Blood pressure is maintained with a mean arterial pressure goal of >75; no neuromonitoring is used. The patient is then placed in a semi-sitting position supported by the horse-shoe headrest with rubber straps for stabilization (Fig. 1).

A C-arm fluoroscopy unit is then introduced to visualize and obtain the correct spinal level. Rarely is there any taping of the shoulders to obtain a view of the lower cervical levels due to gravity. All pressure points are padded, including placement of a pillow at the sacrum.

Prior to the use of the *shower drape* (Large Isolation Drape with 3 M™ Ioban™ 2 Incise Film and Pouch, St. Paul, MN) two split drapes with C-arm covers were used to create the surgical field (Fig. 2). Prior to the advent of commercial tube dilators such as the METRx™ system (Medtronic, Inc., Minneapolis, MN), the senior author used a series of self-retaining speculums to create the surgical corridor (Fig. 3). After injection with a local anesthetic, a 2.5 cm skin incision is made after confirmation with fluoroscopy. Before the laminotomy is performed, the operating microscope is brought into the surgical field and used for the remainder of the case.

Using a high speed pneumatic drill with the TAC-125 drill-bit (Medtronic, Inc., Minneapolis, MN), a small keyhole is created between the lateral 1/3 of the lamina and the medial facet. With visualization of the nerve, a blunt dissector is then used to gently manipulate the nerve root in order to remove the soft fragment of herniated disc. Some patients with a posterior disk/osteophyte complex may require more delicate removal using the high speed drill and a series of curved curettes. For degenerative narrowing of the neural foramina without a fragmented disk or osteophyte complex, bony decompression of the inferior portion of the rostral pedicle with the high speed drill and curved curettes through the foramina is performed. Incision of the disk is not routinely performed; rather disc fragments compressing the exiting nerve are easily dissected and removed. Once the nerve has been decompressed from a medial to lateral direction, a blunt nerve hook is often used to assess the foramen for adequate decompression. It is also possible to take into consideration the pulsation of CSF around the nerve root to assess for adequate decompression with the operating microscope; however, this is not predictive of success in our experience.

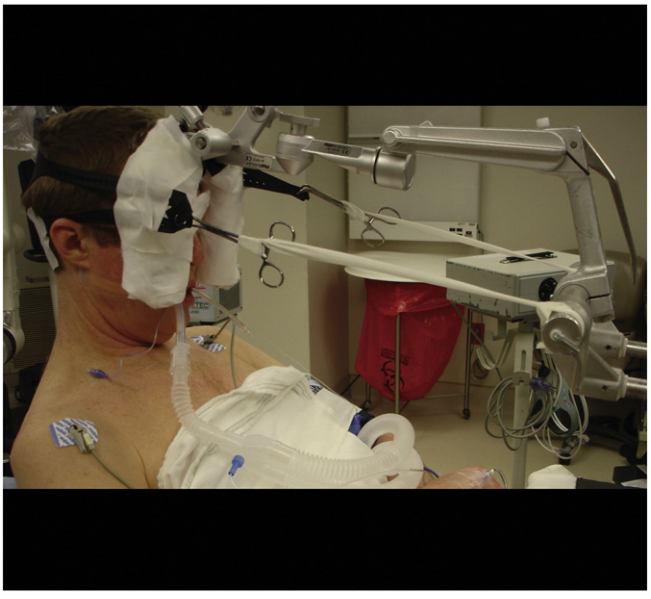

Fig. 1. Minimally invasive posterior keyhole foraminotomy patient positioning setup. This lateral view demonstrates the final setup showing the towel clamps going through the strap and secured to the Mayfield bars with the patient's face lightly pressed against the horseshoe head holder.

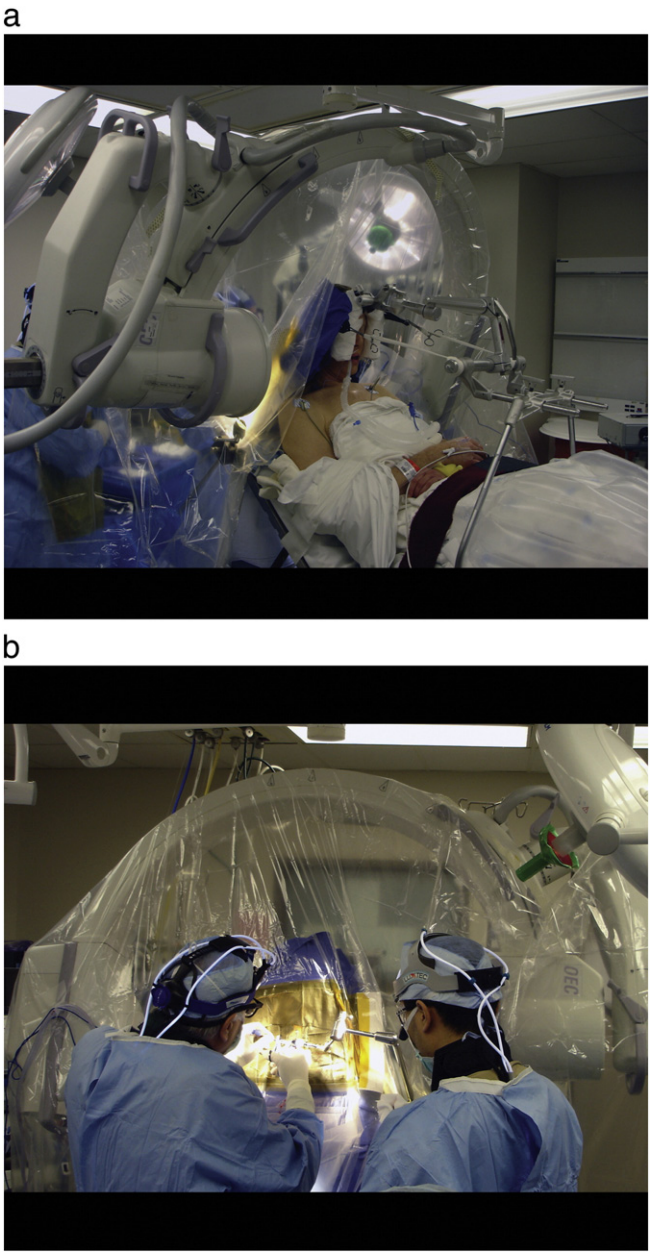

Fig. 2. (a) Shower drape view from the front with the C-arm arched over the patient. (b) Operative view showing a large sterile operative field.

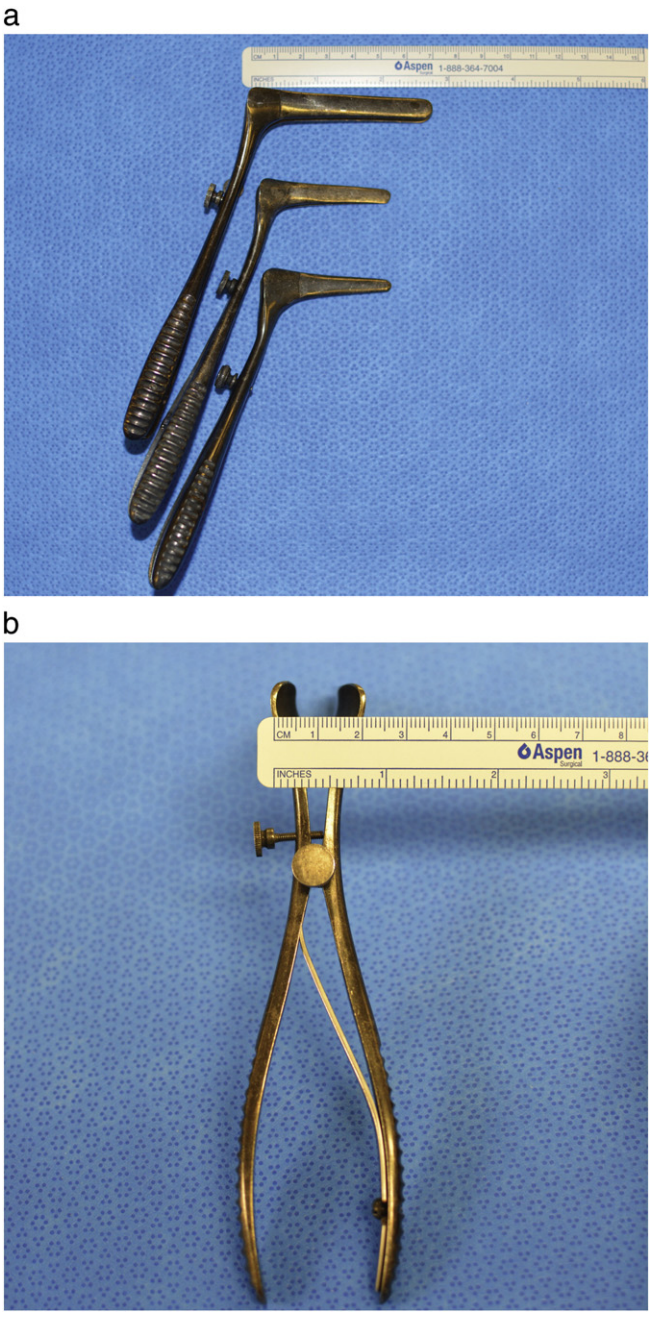

Fig. 3. Self-retaining retractors used prior the commercially available tube-dilators. These were kept open with a latex rubber glove tied at the hand piece.

Standard multilayered closure is performed with subcutaneous absorbable stitches. Patients are routinely discharged from the hospital the same day.

2.1.2. Anterior cervical discectomy and fusion

Fiberoptic endotracheal intubation is routinely utilized in myelopathic patients to avoid further spinal cord injury from excessive neck extension. This procedure is performed routinely without neuromonitoring via a right-sided approach by the senior author. Pre-operative workup for possible vocal cord paralysis with an otolaryngologist is necessary for patients undergoing re-operation.

Folded sheets are placed between the shoulder blades to allow the shoulders to fall away from the c-spine, with a slight extension of the head resting in a donut head-holder. All pressure points are padded to avoid peripheral neuropathies, and the shoulders are taped to the bottom of the operating table only if visualization of lower disc level is inadequate.

The surgical approach to the cervical disc is by way of a transverse incision performed as described by Weinstein [31]; however, a longer incision slightly past midline or laterally across the sternocleidomastoid muscle is used if multilevel surgery is indicated. Intraoperative fluoroscopy is employed to confirm the level, and self-retaining retractor blades are utilized, e.g. Medtronic Shadow-Line® (Medtronic Inc. Minneapolis, MN), to maintain the surgical corridor throughout the case.

The discectomy is performed as routine, only with loupe magnification. Remaining disk/osteophytes are removed with a custom 45° J-shaped angled curette and a high speed pneumatic drill with the 14-

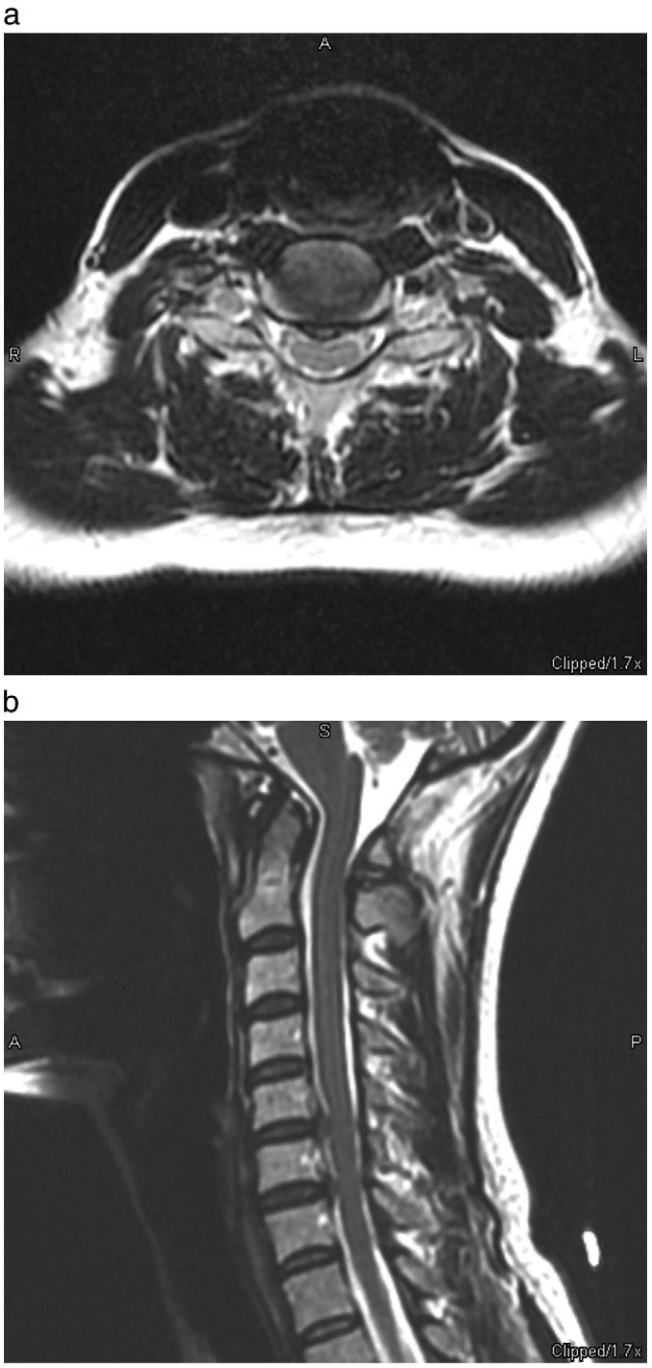

Fig. 4. MRI C-spine from a patient presenting with myeloradiculopthy with degenerative disc and central disc herniations. (Left) Axial T2 imaging showing central disc protrusion at C5–6. (Right) T2 sagittal imaging showing two affected levels of C5-6 and C6-7.

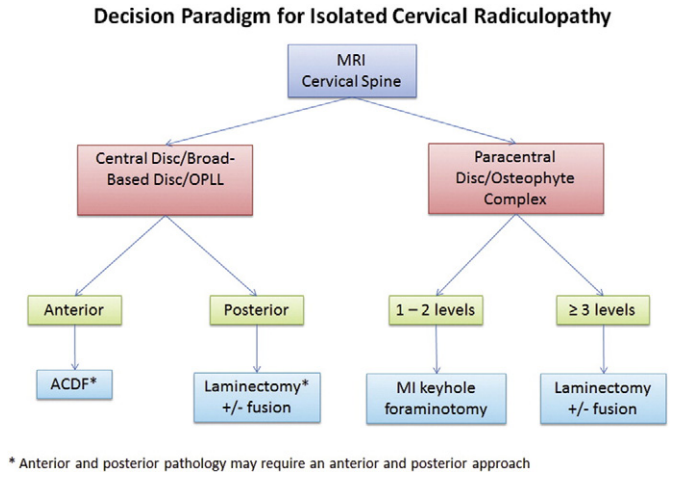

Fig. 5. Decision paradigm for ACDF and MIPKF.

AM diamond burr (Ref. 14BA50DX, Medtronic Inc. Minneapolis, MN). Lastly, the posterior longitudinal ligament is transected, and the dura is visualized.

Autologous bone was routinely harvested from the iliac crest until 2002, when a transition to cadaveric allograft was made. Standard plating and screws are used, and the wound is closed with interrupted sutures in the platysma and an absorbable subcutaneous stitch.

3. Results

The CPT code search criteria allowed for 579 matches. A total of 268 ACDF and 112 MIPKF cases met inclusion criteria. Patient's age, sex, date of surgery, surgical procedure, indications, follow-up dates, and reoperation date (including type of surgery and indications) were recorded in a spreadsheet database. Over the past 15 years, the ACDF group had a total of 7 reoperations (2.6% reoperation rate), and the MIKPF group had 3 reoperations (2.7% reoperation rate).

The ACDF population had an average age of 47.4 ± 9.6 years. The MIPKF population had an average age of 50.2 ± 9.0 years. Ages in the ACDF patients ranged from 22 to 73.3 years while the MIPKF patients ranged from 30.1 to 72.5 years. The median age was 47.5 and 50.4 in ACDF and MIPKF cases, respectively. The ACDF group had 145 males with 123 females, and the MIPKF group contained 78 males and 34 females. Patient follow-up in the ACDF population averaged 11.8 ± 3.0 years, with a median of 11.2 years and a range of 5.5 to 17.9 years. As for the MIPKF population, it had an average follow-up of 6.8 ± 4.4 years, with a median of 5.4 years and a range of 1.0 to 17.9 years

Among the surgical levels, a single level ACDF at C5–6 was the most common with 56 cases, followed by the single level C6–7 and two level C5–6/C6–7 fusion (each with 51 cases) (Chart 1). In the posterior foraminotomy series the most frequent level of operation was C6–7 with 55 cases followed by C5–6 with 27 cases (Chart 2).

Of the 7 ACDF reoperations: 1 case resulted in adjacent level ACDF, one case was a keyhole foraminotomy at the same level as the prior ACDF, four had reoperations with a keyhole foraminotomy at a different level, and one required a C3–7 laminectomy after a C5–6 ACDF five months earlier (Table 1).

With respect to the keyhole foraminotomy surgeries, all three reoperations were ACDFs at the level of the previous operation. Two of the cases were single level keyhole foraminotomies performed at C5–6, which were followed by an ACDF at C5–6 and C6–7 (patient ID#523 and #517) 3.8 years and 2.2 years later, respectively. The third case was a keyhole foraminotomy at C6–7 with a C6–7 ACDF reoperation 2.4 years later (Table 2).

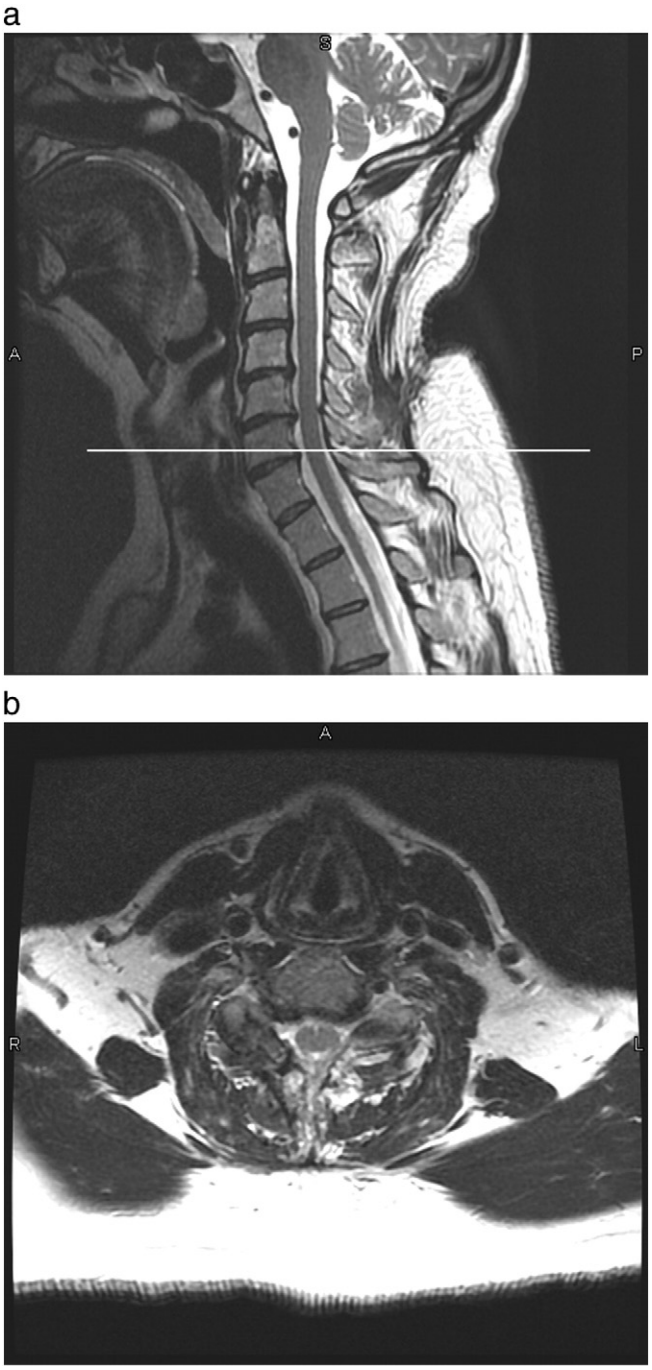

Fig. 6. MRI C-spine from a patient with isolated right C7 radiculopathy. Image on the left confirms the C6–7 level and that on the right demonstrates right foramina stenosis with herniated disc and posterior osteophyte complex.

Patients with more than 2 operations in this series were rare; however, two patients, #64 and #66, had a total of 3 operations (Table 3). Patient #64 underwent a prior two level ACDF at C5–6/C6–7 performed by another surgeon at age 34. He presented to us 15 years later with adjacent segment disease that required a single level fusion at C4–5. He came back 6 years later with a lateral disk on the left at C3–4 which required a MIPKF. Patient #66 had a 2 level ACDF at C5–6/C6–7 performed; however, he returned within the year complaining of recurrent left sided radicular symptoms. A MIPKF procedure was performed at the C6–7 level with relief of his symptoms. He returned 4 years later with adjacent segment disease at C4–5, and a single level ACDF was performed.

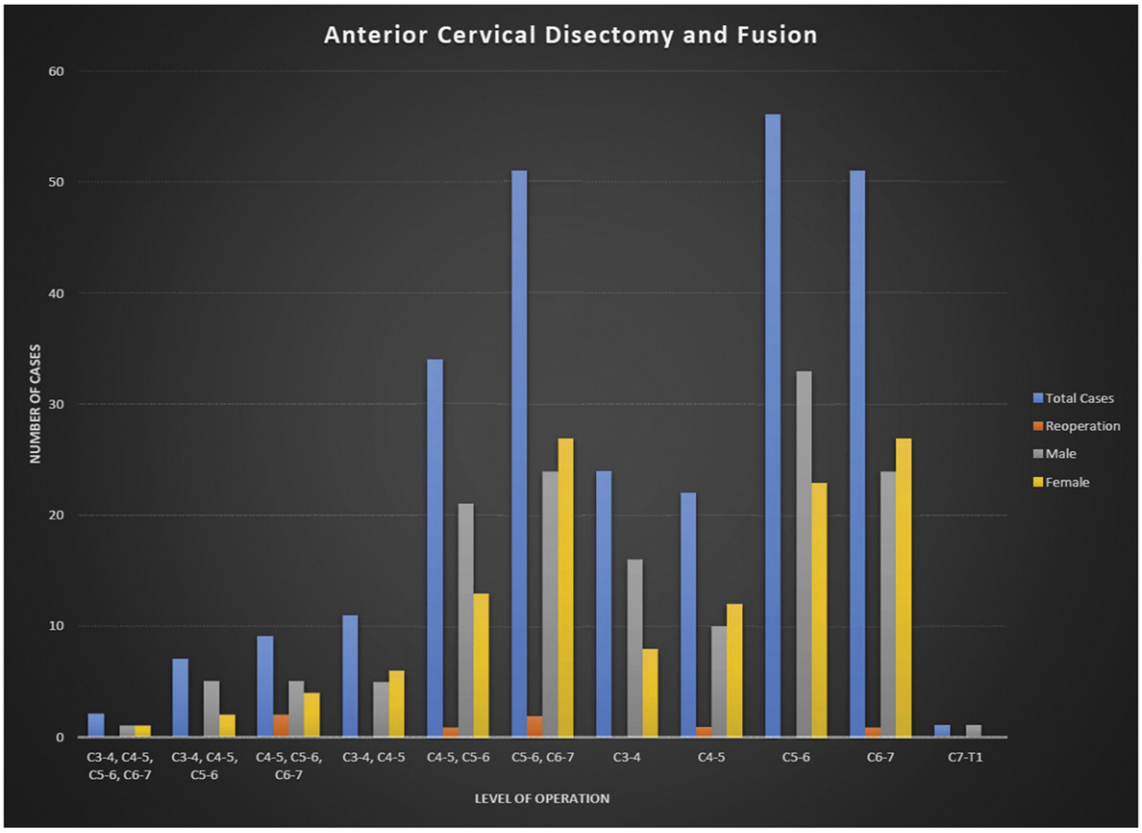

Chart 1. ACDF Procedures 1994–2011.

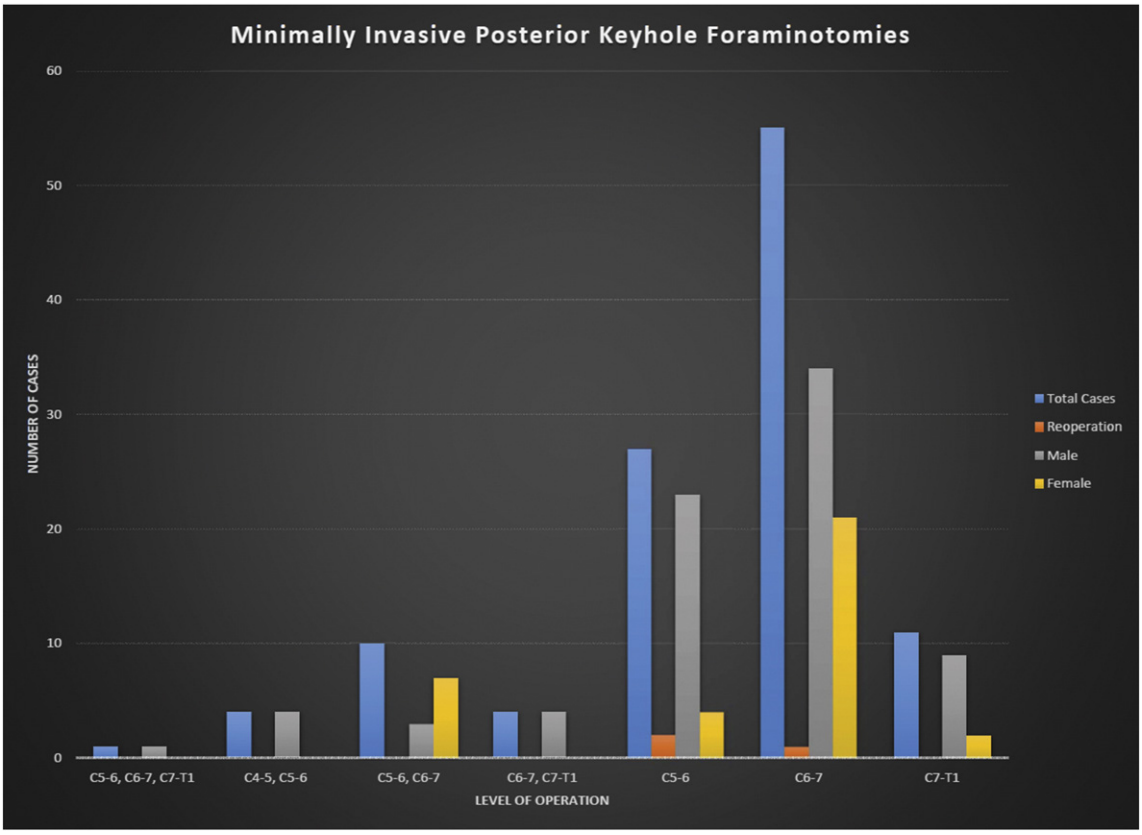

Chart 2. MIPKF Procedures 1994–2011.

Table 1
Initial ACDF surgery requiring reoperation.

Pt. ID	Age	Sex	Procedure	No. Levels	Level	Reoperation (Years)	Procedure	No. Levels	Level of Operation	Reoperation (Years)	Procedure	No. Levels	Level of Operation
11	54	M	ACDF	1	C6–7	4.8	MIPKF (right)	1	C5–6				
38	41	M	ACDF	2	C4–5, C5–6	3.5	ACDF	1	C6–7				
64	49	F	ACDF	2	C5–6, C6–7	15.0	ACDF	1	C4–5	6.44	MIPKF (left)	1	C3–4
66	41	M	ACDF	2	C5–6, C6–7	0.6	MIPKF (left)	1	C6–7	5	ACDF	1	C4–5
272	59	M	ACDF	1	C5–6	0.5	Laminectomy	4	C3–7				
444	30	M	ACDF	2	C5–6, C6–7	1.9	MIPKF (left)	1	C7–T1				
469	48	F	ACDF	3	C4–5, C5–6, C6–7	8.4	MIPKF (left)	1	C7–T1				

Pt. ID: patient identifier, ACDF: anterior cervical discectomy and fusion, MIPKF: minimally invasive posterior keyhole foraminotomy.

4. Discussion

Recent U.S. Medicare data have shown that there are approximately 115,00 cervical spine surgeries performed in the United States annually [32]. Thus, the correct surgical approach is critical to decrease patient morbidity, to avoid reoperations, and to decrease overall healthcare costs.

In this study, we used CPT codes as opposed to International Classification of Disease-9 (ICD-9) codes to focus solely on our surgical patient population. Our results showed that in the ACDF dataset, reoperation occurred in 7 of the 268 patients (2.7%); one of which was due to adjacent segment disc disease. Hilibrand et al., reported the incidence of adjacent-segment disease to be 2.9% (approximately 25.6% at 10 years), but their results were based on radiological follow-up as opposed to rate of reoperation [21]. More recent analysis has shown adjacent segment disease after ACDF to be 11% at 5 years [24].

Our MIPKF dataset had a 2.7% reoperation rate which is comparable to Clarke et al., where 303 cases with a single level posterior foraminotomy demonstrated a 2.9% reoperation rate [27]. Moreover, Henderson et al., reported 846 foraminotomy cases with a 3% reoperation rate for recurrent radiculopathy [5].

4.1. Decision-making/cost consideration

ACDF pioneered by Smith/Robinson [33] and Cloward [34] has been considered a "gold standard" [35] in symptomatic patients who present with radiological imaging showing either a central disc herniation or a broad-based/paracentral disc [26,36] (Fig. 4). Over time we have learned that ACDF is advantageous for restoration of height at the degenerative level [37], thus enlarging the foramen, restoring cervical lordosis [38–41], and thereby contributing to improvement in overall spinal alignment [39,40].

The decision to perform an ACDF versus a posterior keyhole foraminotomy is made on a case-by-case basis, and many times is dependent on surgeon experience. Based on our decision-making paradigm (Fig. 5), patients who have unilateral cervical radiculopathy with radiological findings showing an isolated paracentral disc or a lateral disc/osteophyte complex receive a posterior foraminotomy (Fig. 6). Exceptions include those with ventral pathology in conjunction with bilateral radiculopathy, myelopathy on physical exam, or severe kyphosis. In addition, if three or more levels require decompression, or if central spondylosis is present [14], MIPKF is not recommended [42]. In patients with corresponding radiological findings and myelopathy or myeloradiculopathy on physical exam, an ACDF is recommended.

Given the same benefit or outcome for a specific patient, the risks associated with each procedure are also considered. The ACDF procedure risks include: dysphagia [22,43–45], vocal cord paralysis [46], C5 palsy [47], esophageal perforation, carotid sheath injury, post-operative hematoma, adjacent segment disease [2,19,22,23], and pseudoarthrosis [22]. The MIPKF procedure risks include inadequate decompression or removal of the disk fragment, nerve root injury [15], vertebral artery injury, and risk of air embolism from the semi-sitting position [48–50]. In addition, previous analysis has shown that a single level posterior foraminotomy costs $3570, while a single level ACDF costs $10,078, a difference of $6508 [51]. Thus, in patients with isolated monoradiculopathy from a lateral disk/osteophyte complex, the MIPKF procedure may provide advantages such as preservation of cervical motion, reduced morbidity, and lower direct cost.

5. Limitations

Because this case series is a retrospective review, follow-up physical examination and radiological imaging in patients after completed treatment are inherently limited. The true number of patients who have improved symptoms or who have completely recovered cannot be determined, and even those who worsened may have sought second opinions. Overall, this analysis focused on an objective endpoint, whether another surgical intervention was required. The authors also emphasize that this case series does not suggest superiority of MIPKF to ACDF or vice versa, but the former may provide adequate benefit with decreased risk in patients with isolated monoradiculopathy from a lateral disk/osteophyte complex.

6. Conclusion

In conclusion, there are still controversies in the surgical management of degenerative cervical spine pathology. Successful outcomes depend on surgeon selection of the appropriate approach for the individual patient. Of note, patients with monoradiculopathy and a paracental disc may benefit from a MIPKF procedure, as the risk of reoperation is similar to that of an ACDF.

Table 2
Initial MIPKF surgery requiring reoperation.

Pt. ID	Age	Sex	Procedure	No. Levels	Right vs Left Side	Level	Reoperation (Years)	Procedure	No. Levels	Level of Operation
517	54	M	MIPKF	1	L	C5–6	2.21	ACDF	2	C5–6, C6–7
523	30	M	MIPKF	1	L	C5–6	3.76	ACDF	2	C5–6, C6–7
562	57	F	MIPKF	1	R	C6–7	2.37	ACDF	1	C6–7

Pt. ID: patient identifier, ACDF: anterior cervical discectomy and fusion, MIPKF: minimally invasive posterior keyhole foraminotomy.

Table 3
Patients that required multiple (>2) cervical spine surgeries.

Pt. ID	Age	Surgery	Level
64	34	ACDF	C5–6, C6–7
	49	ACDF	C4–5
	55	MIPKF	C3–4
66	41	ACDF	C5–6, C6–7
	41	MIPKF	C6–7
	46	ACDF	C4–5

Pt. ID: patient identifier, ACDF: anterior cervical discectomy and fusion, MIPKF: minimally invasive posterior keyhole foraminotomy.

Disclosures/Conflict of Interest statement

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Institutional Review Board

George Washington University IRB Protocol # 100724.

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