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Comparison of the Outcomes of Microendoscopic Cervical Foraminotomy versus Full-endoscopic Cervical Foraminotomy for the Treatment of Cervical Radiculopathy

Blumstein Gideon,[1,2] Kento Takebayashi,[1,3] Takahiro Inui,[4] Yasushi Oshima,[5,6] Hiroki Iwai,[1,6] Hirohiko Inanami,[1,6] and Hisashi Koga[1,3]

[1]*Department of Orthopaedics, Iwai Orthopaedic Medical Hospital, Tokyo, Japan*
[2]*Department of Orthopaedics, Cedars Sinai Marina Del Rey Hospital, Marina Del Rey, CA, USA*
[3]*Department of Neurosurgery, Iwai FESS Clinic, Tokyo, Japan*
[4]*Department of Orthopaedic Surgery, Teikyo University School of Medicine, Tokyo, Japan*
[5]*Department of Orthopaedic Surgery, The University of Tokyo, Tokyo, Japan*
[6]*Department of Orthopaedic Surgery, Inanami Spine and Joint Hospital, Tokyo, Japan*

Abstract

This study aimed to compare the outcomes of microendoscopic cervical foraminotomy (MECF) versus full-endoscopic cervical foraminotomy (FECF) for treating cervical radiculopathy (CR).
A retrospective study was performed on patients with CR treated using MECF (n = 35) or FECF (n = 89). A 16-mm tubular retractor and endoscope was used for MECF, while a 4.1-mm working channel endoscope was used for FECF. Patient background and operative data were collected. The numerical rating scale (NRS) and the Neck Disability Index scores were recorded preoperatively and at 1 year postoperatively. Postoperative subjective satisfaction was also assessed.
Although the NRS, and NDI scores, as well as postoperative satisfaction at 1 year considerably improved in both groups, one of the background data (number of operated vertebral level) was significantly different. Therefore, we separately analyzed single- and two-level CR. In single-level CR, operation time, intraoperative bleeding, postoperative stay, NDI after 1 year, and reoperation rate were statistically superior in FECF group. In two-level CR, the postoperative stay was statistically superior in FECF group. Three postoperative hematomas were observed in the MECF group, while none was observed in the FECF group.
Operative outcomes did not significantly differ between groups. We did not observe postoperative hematoma in FECF even without placement of a postoperative drain. Therefore, we recommend FECF as the first option for the treatment of CR as it has a better safety profile and is minimally invasive.

Keywords: cervical radiculopathy, full-endoscopic cervical foraminotomy, minimally invasive, microendoscopic cervical foraminotomy

Introduction

Cervical radiculopathy (CR) gives rise to severe unilateral neck, trunk, and arm pain. The pain is frequently strengthened by neck retro- or lateroflexion and disturbs daily activities of the patients. CR is caused by the compression of cervical nerve roots around the vertebral foramen. This compression occurs by impingement due to disk herniation, foraminal stenosis, or bony osteophytes. These pathologies frequently occur simultaneously.[1-4)] While CR can often cause significant symptoms and may be debilitating, typically 75%-90% of patients achieve symptomatic improvement with conservative treatment.[3,5)] For patients who are persistently symptomatic despite conservative

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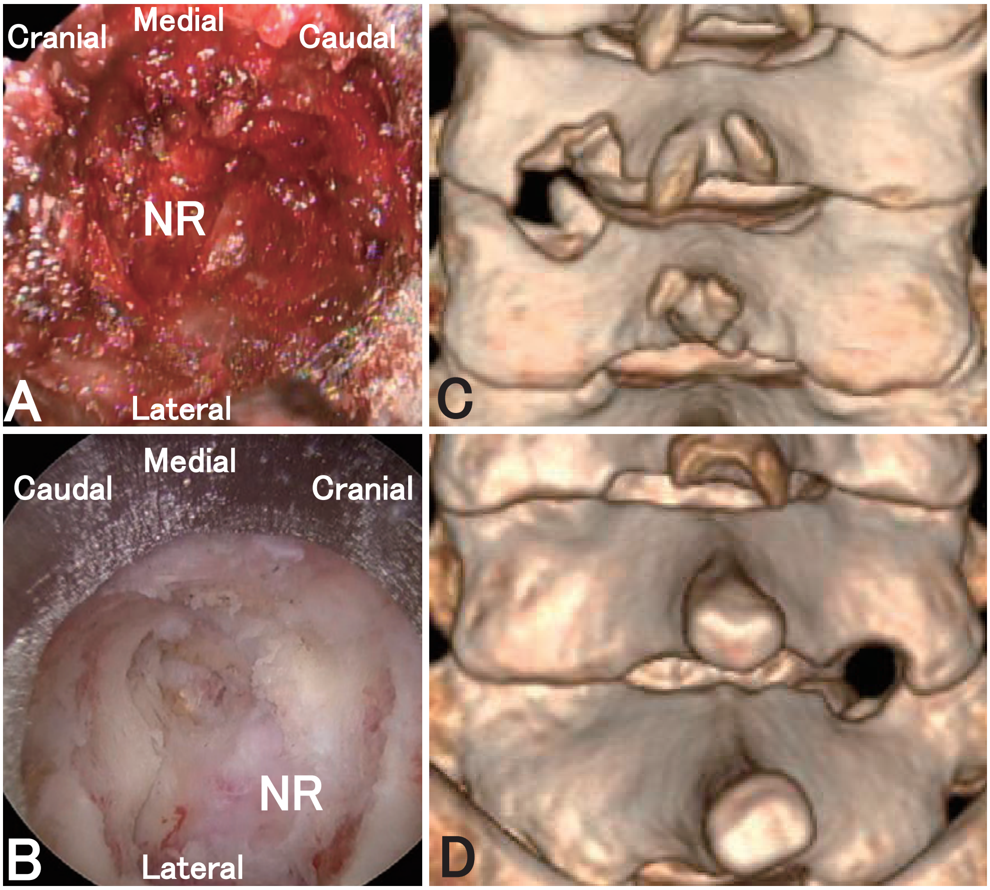

Fig. 1 Comparison between intraoperative visual fields (A, B) and postoperative CT findings (C, D) between MECF (A, C) and FECF (B, D). Note that a clear visual field is obtained by FECF without bleeding (B). Enough decompression is achieved through small outer bone window by FECF (D). NR in the intraoperative visual fields indicates the exiting nerve root.

treatment, or those who have a significant functional deficit (e.g., motor weakness or sensory deficits), surgical treatment should be considered.

There are several strategies for the treatment of CR.[6-10] Among these, we have reported good operative outcomes of microendoscopic cervical foraminotomy (MECF) and full-endoscopic cervical foraminotomy (FECF).[11-14] The microendoscope is a combination of a tubular type retractor and endoscope and has been widely used in Japan, while the use of full-endoscopic surgery is gradually increasing and replacing the microendoscope as the leading minimally invasive spine surgery technique. Both approaches are minimally invasive, but comparative analysis between MECF and FECF is not reported yet. Therefore, we compared not only operative outcomes but also their minimal invasiveness to clarify which is the preferred approach for the treatment of CR.

Materials and Methods

Study design: Retrospective comparative study

Patient selection

Between January 2016 and March 2020, 311 consecutive patients with CR who underwent MECF using the METRx endoscopic system (Medtronic Sofamor Danek, Memphis, TN, USA) or FECF using a 4.1-mm working channel endoscope (RIWOspine GmbH, Knittlingen, Germany) were included (Fig. 1). All patients were diagnosed with CR refractory to nonoperative medical treatment, physical therapy, and/or nerve blocks. Patients in whom we could not distinguish whether the radiculopathy was caused by combined upper cervical spinal canal stenosis or other diseases (facet cyst, etc.) were excluded. Patients in whom we could not obtain their 1-year follow-up data were also excluded. Finally, 35 and 89 patients in the MECF and FECF groups, respectively, were analyzed in this study.

All procedures involving human participants were in accordance with the ethical standards of the research committee of the Iwai Medical Foundation (IRB approval No. 20230405) and with the 1964 Helsinki Declaration. In-

Table 1 Demographic data of 124 patients

Variables		MECF (N = 35)	FECF (N = 89)	P value
Age, mean (SD)		54.4 (10.3)	54.3 (10.4)	0.97
Sex (male) [n (%)]		31 (89%)	73 (82%)	0.37
BMI (SD)		24.6 (3.3)	23.5 (3.3)	0.092
Radiculopathy side [n (%)]	Right	12 (34%)	31 (35%)	0.95
Single- or multilevel	Single-level	26 (74%)	83 (93%)	0.009
	Two-level	8 (23%)	6 (7%)	
	Three-level	1 (3%)	0 (0%)	
NRS of upper extremity, mean (SD)	Before surgery	6.3 (2.8)	5.5 (3.0)	0.13
	At discharge	1.6 (1.7)	1.3 (1.4)	0.23
	After 1 year	2.4 (2.6)	1.6 (2.2)	0.10
NDI, mean (SD)	Before surgery	18.3 (9.1)	15.4 (6.7)	0.055
	After 1 year	8.4 (8.1)	6.0 (4.2)	0.034
Satisfaction after 1 year		2.6 (1.6)	2.1 (1.4)	0.093

BMI, body mass index; NRS, numerical rating scale; NDI, neck disability index; MECF, microendoscopic cervical foraminotomy; FECF, full-endoscopic cervical foraminotomy; SD, standard deviation

Table 2 Univariate analysis of operative outcomes for single-level radiculopathy

Variables		MECF (N = 26)	FECF (N = 83)	P value
Vertebral level [n (%)]	C4/5	4 (15%)	4 (5%)	0.071
	C5/6	11 (42%)	31 (37%)	0.65
	C6/7	11 (42%)	42 (51%)	0.46
	C7/T1	0 (0%)	6 (7%)	0.16
Operation time (min), mean (SD)		71.9 (23.4)	61.0 (18.9)	0.018
Intraoperative bleeding (mL), mean (SD)		15.5 (19.2)	10.0 (0.0)	0.010
Postoperative hospital stay (days), mean (SD)		5.0 (1.4)	2.0 (0.9)	<0.001
NRS of upper extremity, mean (SD)	Before surgery	6.0 (3.0)	5.6 (2.9)	0.55
	At discharge	1.6 (1.8)	1.2 (1.5)	0.33
	After 1 year	2.5 (2.7)	1.7 (2.3)	0.14
NDI, mean (SD)	Before surgery	17.9 (9.2)	15.3 (6.7)	0.12
	After 1 year	8.9 (8.8)	6.2 (4.2)	0.036
Satisfaction after 1 year		2.8 (1.7)	2.1 (1.3)	0.060
Reoperation		3 (12%)	1 (1%)	0.041

NRS, numerical rating scale; NDI, neck disability index; MECF, microendoscopic cervical foraminotomy; FECF, full-endoscopic cervical foraminotomy; SD, standard deviation

formed consent for inclusion in the study was obtained as part of the preoperative consent obtained prior to surgery and provided to the patients.

Data collection

Patient background data, such as age, sex, body mass index (BMI), vertebral levels of CR, and side of CR, were collected (Table 1). Preoperative T2-weighted magnetic resonance imaging (MRI) and computed tomography (CT) were performed to determine the vertebral level and the pathology of CR. Postoperative MRI and CT were used for the confirmation of decompression of the corresponding nerve root.

Data on operation time, intraoperative bleeding, postoperative hospital stay, complications related to the operation, and recurrence were obtained from medical records (Tables 2 and 3). The intraoperative bleeding was calculated to subtract the amount of irrigation saline from the

Table 3 Univariate analysis of operative outcomes for two-level radiculopathy

Variables		MECF (N = 8)	FECF (N = 6)	P value
Vertebral level [n (%)]	C4/5	1 (12%)	0 (0%)	1.00
	C5/6	6 (75%)	5 (83%)	1.00
	C6/7	6 (75%)	6 (100%)	0.47
	C7/T1	3 (38%)	1 (17%)	0.58
Operation time (min), mean (SD)		107.6 (27.2)	122.7 (34.3)	0.38
Intraoperative bleeding (mL), mean (SD)		12.5 (7.1)	10.0 (0.0)	0.41
Postoperative hospital stay (days), mean (SD)		4.8 (1.0)	1.3 (0.5)	<0.001
NRS of upper extremity, mean (SD)	Before surgery	7.0 (1.6)	3.0 (3.3)	0.011
	At discharge	1.9 (1.7)	1.7 (0.8)	0.79
	After 1 year	2.4 (2.4)	0.7 (1.2)	0.14
NDI, mean (SD)	Before surgery	17.6 (8.5)	15.8 (7.3)	0.69
	After 1 year	7.0 (6.3)	4.2 (3.6)	0.35
Satisfaction after 1 year		2.5 (1.4)	2.3 (2.0)	0.86
Reoperation		1 (12%)	0 (0%)	1.00

NRS, numerical rating scale; NDI, neck disability index; MECF, microendoscopic cervical foraminotomy; FECF, full-endoscopic cervical foraminotomy; SD, standard deviation

amount of suction. As 10 mL was the lowest data from this formula in both MECF and FECF groups, we determine that the measuring limit was 10 mL and unmeasurable cases were recorded as 10 mL. The degree of arm pain was evaluated using the numerical rating scale (NRS) at hospital admission, discharge, and 1 year postoperatively. The degree of disability was evaluated using the pre- and postoperative Neck Disability Index scores (these scores range from 0 to 50, with higher scores indicating more disability related to CR). Postoperative subjective satisfaction was also assessed, using a seven-level rating scale (these scores range from 1 to 7, with the highest score being extremely unsatisfied and the lowest score being extremely satisfied).[11]

Statistical analysis

Demographic data and outcome measures were compared between the two groups using the t-test and chi-square test for continuous and categorical variables, respectively. Pre- and postoperative outcome measures were compared using the paired t-test. All analyses were performed using STATA version 16.0 (Stata Corp. LLC, College Station, TX, USA). A two-sided *P* value of <0.05 was considered statistically significant.

Surgical technique

Patients were carefully logrolled to the prone position. Surgery was performed under general anesthesia. Neuromonitoring was performed utilizing motor-evoked potentials. During the operation, fluoroscopy was used to verify correct placement of the endoscope or microendoscope.

Ten skilled surgeons performed the MECF surgeries. The surgical techniques were performed according to Adamson's report.[6] An 18-mm skin incision was made approximately 20 mm lateral to the midline of the operated level. A sheath with an outer diameter of 16 mm was placed on the cervical lamina after splitting the paravertebral muscles. Under microendoscopic assistance, the caudal side of the upper vertebra and the cranial side of the lower vertebra were resected using a surgical drill and a Kerrison rongeur. Subsequently, the whole circumference of the nerve root was carefully exposed. Skin closure was performed and a drainage tube was placed.

Six skilled surgeons performed FECF using a 4.1-mm working channel endoscope. The surgical techniques have been described in detail in our previous reports.[12-14] An 8-mm skin incision was made approximately 15 mm lateral to the midline of the operated level. A working sheath with an outer diameter of 7 mm was placed on the cervical lamina after splitting the paravertebral muscles. Decompression was performed in a similar fashion to MECF, utilizing a full-endoscopic visual field with continuous irrigation.

Results

Table 1 summarizes the demographic data of the patients. This retrospective study included 35 patients (31 men, 4 women) and 89 patients (73 men, 16 women) in the MECF and FECF groups, respectively. The mean age at surgery was 54.4 and 54.3 years in the MECF and FECF groups, respectively. The mean BMI was 24.6 and 23.5 in the MECF and FECF groups, respectively. CR side (right) was 34% and 35% in the MECF and FECF groups, respectively. There were no statistically significant differences in patient background, but there was a significant difference in single- or multilevel operation ($P = 0.009$). Operative outcomes evaluated NRS and NDI scores significantly improved after operation in both groups ($P < 0.001$). NDI after 1 year was statistically lower in FECF group, and other scores including postoperative satisfaction were almost identical in both groups.

According to the difference of single- or multilevel operation, we further separately analyzed single- and two-level operation. There was no distribution difference of operated vertebral level (Tables 2 and 3). In addition to NDI after 12 months, operation time, intraoperative bleeding, postoperative stay, and reoperation rate were statistically superior in the FECF group in single-level analysis (MECF, 26 cases; FECF, 83 cases) (Table 2). Regarding complications, postoperative hematoma occurred in two patients in the MECF group, and both patients underwent reoperation on the same day for evacuation of hematoma. One patient in each group underwent reoperation for recurrent CR during the follow-up periods.

In two-level analysis (MECF, eight cases; FECF, six cases), postoperative stay was shorter in the FECF group; this was statistically significant. Postoperative hematoma occurred only in the MECF group; however, this was not statistically significant.

Discussion

Although different surgical strategies have been used to treat CR, including anterior cervical decompression and fusion, disk replacement, and posterior cervical foraminotomy, all strategies have been effective.[2,5,15] Among them, posterior cervical foraminotomy has some variation for the approach such as open or minimally invasive approach using a microscope or endoscope. Several studies have demonstrated that posterior cervical foraminotomy has good clinical outcomes using both the open and minimally invasive approach.[3,4] However, the minimally invasive approach showed better outcomes regarding blood loss, operative time, and hospital stays than the open approach.[2,16-18] In response to the early report of favorable outcomes of microendoscopic cervical foraminotomy (MECF) in 2002,[19] we have been performing MECF for patients with severe CR since 2012 and have reported good operative outcomes.[11] Since 2016, we also started to perform FECF following Rutten's report of favorable outcomes.[10] Moreover, we reported good operative outcomes of FECF and have gradually shifted from MECF to FECF.[12-14] In this study, we compare the operative outcomes and minimal invasiveness of MECF and FECF using the data of the transition period from MECF to FECF in our hospital.

The number of patients undergoing MECF was lower than that of FECF because FECF was mainly selected in the latter part of this transition period. Multilevel operation in the FECF group was lower than that in the MECF group because during this transition period, we initially performed single-level FECF to establish safety and transitioned to performing multilevel FECF at the latter half of this period. Currently, we are performing multilevel of FECF. Operative outcomes evaluated by NRS and NDI scores did not significantly differ between groups. Although the NDI 1 year after FECF was statistically lower than that of MECF in total and single-level analyses, other score significantly improved in both groups. Furthermore, postoperative satisfaction was also similarly good, and it should be concluded that good operative outcomes can be obtained by both operations. Preoperative NRS score of FECF in two-level analysis was statistically lower than that of MECF because the main symptom in FECF groups was motor weakness of upper extremity rather than arm pain (five out of six cases).

Our analysis showed that single-level FECF was superior in terms of operative time (shorter), safety profile (safer), and invasiveness (minimal). Even in the two-level FECF, we demonstrated shorter hospital stay. Reoperation rate in the FECF group was statistically lower than that in the MECF group. The intraoperative bleeding was less than the measuring limit in 51 FECF cases and 10 mL in 38 FECF cases; however, more than 50 mL of intraoperative bleeding was observed in 2 MECF cases. Absorbable hemostatic gauze and/or hemostatic agents such as Floseal were used for four MECF cases but were not required in the FECF cases. The fact that FECF is minimally invasive to the surrounding tissues (bone, muscle, and ligament) might not only affect the operation time but also contribute to reduce both intra- and postoperative bleeding. Furthermore, postoperative drainage tube was not required for FECF except initial seven FECF cases.

This study has some limitations. This is a retrospective and single-institution study; however, we tried to adjust the patient background between the two groups and were able to demonstrate the noninferiority of FECF over MECF on both short-term and 1-year postoperative results. Furthermore, we showed a potential advantage of FECF in reducing intra- and postoperative bleeding, thereby also reducing the usage of hemostasis reagents and drainage tube.

Full-endoscopic spine surgery necessitates longer training for trainee surgeons to acquire the required surgical skills.[20,21] However, after acquisition of the skills by performing full-endoscopic lumbar surgeries, the surgeons are able to perform posterior cervical foraminotomy without any additional training; all five surgeons (except H.K who is an instructor) who performed FECF in this study started FECF after training for 30 cases of lumbar FESS surgeries. For surgeons with sufficient lumbar FESS surgical experience, FECF will be a better alternative to other conventional CR surgeries.

Conclusions

This retrospective study with 1-year follow-up period demonstrated that operative outcomes of MECF and FECF (using a 4.1-mm working channel) for treating CR were not significantly different. In addition to the minimal invasiveness (less bleeding, short hospital stay), FECF has the potential advantage of reducing postoperative hematoma.

Conflicts of Interest Disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Corresponding author: Hisashi Koga, MD, PhD.
Department of Neurosurgery, Iwai FESS Clinic, 8-18-4 Minamikoiwa, Edogawa-ku, Tokyo 133-0056, Japan.
e-mail: hkoga0808@gmail.com