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REVIEW ARTICLE

Microsurgery or open cervical foraminotomy for cervical radiculopathy? A systematic review

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Abstract

Objective The purpose of this article was to systematically review the clinical outcomes of microendoscopic foraminotomy compared with the traditional open cervical foraminotomy.

Methods A literature search of two databases was performed to identify investigations performed in the treatment of cervical foraminotomy with microsurgery or an open approach. Data including blood loss, surgical time, hospital stay, complications, clinical success rate, reduction of arm and neck pain, improvement of neurological function, and repeated surgery rate were summarized, calculated and compared. Results of clinical success were performed by calculattng effect indicators and standard errors based on a single rate to assess heterogeneity in the two groups.

Results The initial literature search resulted in 713 articles, of which, 26 were determined as relevant on abstract review. An open foraminotomy approach was performed in 16 and a microsurgery approach in ten studies. The open group demonstrated minimal to moderate heterogeneity, with I^2 value of 27 %; and microsurgery group demonstrated minimal heterogeneity, with I^2 value of 1 %. Aggregated data found that patients treated by microsurgery foraminotomy have lower blood loss by 100.1 ml (open: 149.5 ml, microsurgery: 49.4 ml, $n = 1257$), shorter surgical time by 24.9 minutes (open 88.7 minutes, microsurgery 63.8 minutes, $n = 1423$),and shorter hospital stay by 3.0 days (open 4.1 days, microsurgery 1.1 days, $n = 1350$), compared with patients treated by open cervical foraminotomy. The pooled clinical success rate was 89.7 % [confidence interval (CI) 87.7–91.6) in the open group versus 92.5 % (CI 89.9–95.1) in the microsurgery group, with no statistical difference ($p = 0.095$). Overall complication rates were not statistically significant between groups ($p = 0.757$). The incidence of dural tears was 1.07 %(12/1121) in patients undergoing microsurgery versus 0.27 % (2/745) for open surgery ($p = 0.091$). The incidence of infection was 0.54 % (6/1121) in patients undergoing microsurgery versus 0.40 % (3/745) for open surgery ($p = 0.949$). The incidence of root injury was 0.80 % (9/1121) in patients undergoing microsurgery versus 1.48 % (11/745) for open surgery ($p = 0.166$). Revision surgery occurred in 2.32 % (27/1163) in the microsurgery group versus 3.35 % (28/835) for traditional surgery, with no statistical difference ($p = 0.164$). Pooled reduction in visual analogue scale for the arm (VASA) was 75.0 % (CI 66.0–84.0) in the open group and 87.1 % (CI:76.7, 97.5) in the microsurgery group, with no statistical difference ($p = 0.065$). Pooled reduction in VAS of the neck (VASN) was 66.2 % (CI:52.2, 80.2) in the open group and 68.1 % (CI:36.4, 99.8) in the microsurgery group, with no statistical difference($p = 0.894$). Pooled improvement in neurological function was 55.3 % (CI:18.6, 91.9) in the open group and 64.9 % (CI:34.6, 95.2) in the microsurgery group, with no statistical difference ($p = 0.576$).

Conclusions Although advantages of cervical microsurgery are less blood loss and shorter surgical time and hospital stay over the standard open technique, there is no significant difference in clinical success rate, complication rate, reduction of arm and neck pain and improvement of neurological function between microsurgery and open cervical foraminotomy.

Keywords Open cervical foraminotomy · Minimally invasive spinal surgery · Microendoscopic foraminotomy · Clinical outcomes · Complications · Systematic review

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Introduction

Minimally invasive spinal surgery (MISS) represented by microendoscopic discectomy (MED) has been developing rapidly since the 1980s. Percutaneous technology, endoscopic technology and minimal-access technology are three kinds of commonly used minimally invasive surgery, the application range of which extends from the thoracolumbar region to the cervical spine. Further, due to extraordinary advances in microsurgery techniques, allowing care and treatment of cervical radiculopathy, microsurgery of the cervical spine has become a focus of research. An increasing number of studies reported little trauma, reduced blood loss, shorter hospital stays faster recovery times and safety and reliability as advantages via microendoscopic foraminotomy [1–5].

There is no doubt that the minimally invasive concept is an important direction for development of the cervical spine. However, almost all scholars agree that indications for microsurgery should be aimed at a small range of soft lesions, such as single- or double-segments intervertebral disc pathological changes; large or complex pathological changes, such as cervical ossification of the posterior longitudinal ligament are not suitable for microsurgery [6–8]. Another problem that cannot be ignored is that microsurgery techniques often deal with part of the pathological disc, which is not removed completely, and may result in complications, such as intervertebral disc degeneration or infection [9]. Only a few high-level, evidence-based literature reports are available regarding the clinical effect from different angles between microsurgery and open surgery [10]; there remains considerable debate about the use of open or microsurgery techniques for treating cervical radiculopathy. The purpose of this article was to systematically review clinical outcomes of microendoscopic foraminotomy compared with the traditional open cervical foraminotomy.

Materials and methods

Literature review

Our systematic review conforms to recommendations in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [11]. We conducted a systematic literature search in PubMed, MEDLINE (OVID interface) between January 1990 and December 2015. Procedures included in this review were cervical foraminotomy or laminoforaminotomy for open methods or microsurgery approaches (including cervical endoscopic, full endoscopic, microendoscopic and microscopic approaches). Inclusion criteria in were English language, adult only, subaxial spine, radiculopathy treated with a cervical foraminotomy and minimum of 15 patients for a given study with an available full text. Studies were excluded if they involved interbody fusion, revision surgery, trauma, intervertebral disc replacement, vertebral body replacement or tumour cases.

The abstracts of each article were reviewed by two independent authors to assess for inclusion in the review. All authors then jointly reviewed full texts and extracted the following data: study design, patient demographics, surgical procedures performed, spine segment treated, surgical results, reported complications and follow-up results. Discrepanceis were resolved by consensus. Level of evidence ratings was assigned to each article independently using criteria of the Centre for Evidence-Based Medicine (CEBM) Levels of Evidence 2.1. http://www.cebm.net/index.aspx?o=5653.

Statistical analysis

The quality of included studies was assessed based on the CEBM, and statistical heterogeneity between studies was evaluated with the I^2-statistic [results of clinical success were performed by calculating effect indicators and standard errors (SE) based on single rate using the RevMan software, version 5.2); I^2 values <25 % indicate consistent results and homogeneous studies in the same group. The data extracted were number of patients; patient age; time of follow-up; blood loss (blood loss that could not be measured was assumed to be 5 ml), surgical time, hospital stay (discharged the same day: 0.5 patient days; the next day: 1.0 patient days); reduction of arm and neck pain [visual analogue scale of the arm (VASA)/ visual analogue scale of the neck (VASN), preoperative VAS,

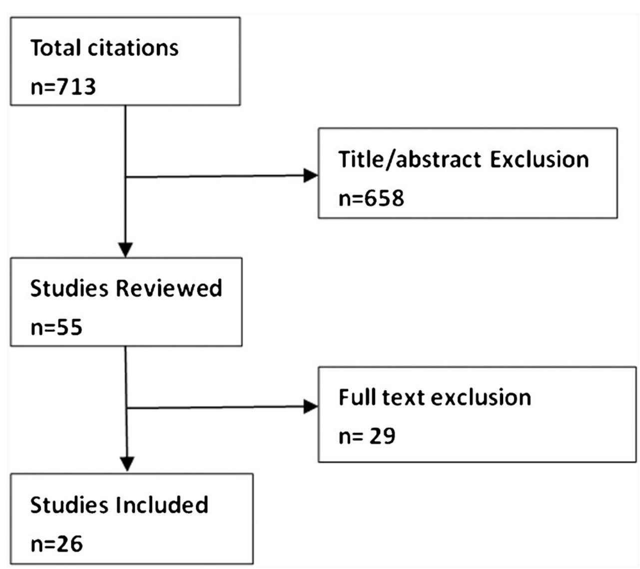

Fig. 1 Systematic review process to select studies

Table 1 Summary of studies in the open group

Study	Level of evidence	No. patients	Age (years)	Follow-up (months)	Procedure
Kang et al. [2] 2014	3	117	52.1	36.1	PCF
Park et al. [3] 2013	4	50	51	105.6	AF
Jho et al. [35] 2002	4	104	46	36	AF
Kim et al. [29] 2009	1	19	54.1	34.2	PCF
Cornelius et al. [36] 2007	4	40	50.6	51.6	AF
Holly et al [30] 2007	4	21	51	23	PCF
Witzmann et al [37] 2000	4	57	43.4	37.2	PCF
Chang et al. [31] 2011	4	34	53.6	18	PCF
Korinth et al. [32] 2006	3	168	46.9	72.1	PCF
Skovrlj et al. [38],2014	3	70	50.5	26	PCF
Winder et al. [12] 2011	3	65	51.2	NR	PCF
Choi et al. [42] 2007	3	20	48.7	16.7	AF
Kotil et al. [39] 2007	3	25	51.8	25.3	AF
Saringer et al. [40] 2002	4	34	43.8	8.2	AF
Balasubramanian et al. [41] 2008	4	34	48.1	5.6	AF
Grieve et al. [33] 2000	4	62	52	40	PCF

AF anterior foraminotomy, *PCF* posterior cervical foraminotomy, *NR* not reported

postoperative VAS/preoperative VAS)]; improvement of neurological function based on the Neck Disabilitv Index (NDI) or the North American Spine Society Instrument Score (NASS); post-operative score; pre-operative score/pre-operative score; complications, clinical success rate (excellent/good equaling success and fair/poor equaling failure based on the Odom or Prolo criteria or complete remission was reported); and repeated surgery rate. Data were summarized, calculated and compared.

Comparison between groups was performed using the *t* test for analysis of metric scaled data and the ci-square test for analysis of categorical data (SPSS software, version 18.0). Confidence intervals were reported at 95 % levels. *P* values <0.05 were considered statistically significant.

Results

Study selection

An initial search found 713 papers published between January 1990 and December 2015. Among them, 658 were excluded

Table 2 Summary of studies included in the microsurgery group

Study	Level of evidence	No. patients	Age (years)	Follow-up time (months)	Procedure
Ruetten S et al. [5],2008	1	100	43	24	Full endoscopic
Winder MJ et al. [12],2011	3	42	50.7	NR	Microscopic
Kim CH et al. [13],2015	3	44	50.5	23	Microscopic
Branch BC et al. [14],2015	4	463	49.6	14	Microscopic
Deukmedjian AJ et al. [15],2013	4	66	40	3	Full endoscopic
Minamide A et al. [34],2010	4	51	62.9	20.3	Microendoscopic
Fessler RG et al. [16],2002	2	25	49.6	4.6	Microendoscopic
Hilton Jr. et al. [17],2007	4	222	49	26	Microscopic
Yadav YR et al. [18],2014	4	50	55.4	19	Endoscopic
Ruetten S et al. [19],2007	4	100	44	24	Full endoscopic

NR not reported

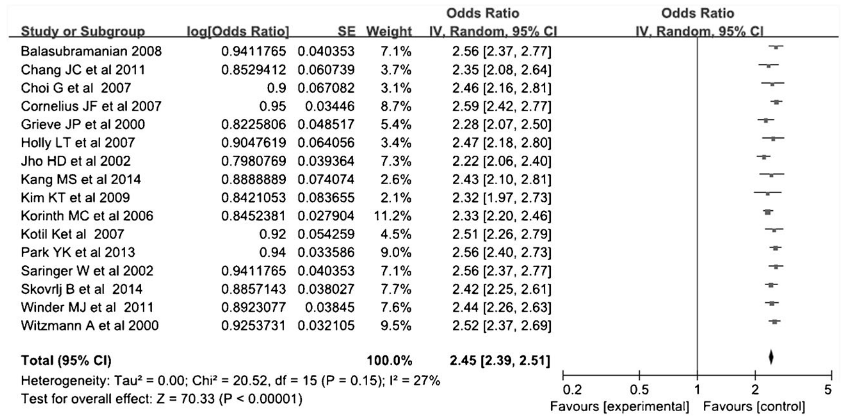

Fig. 2 Logit event rate by study in the open group

because they were not full-text studies. The remaining 55 citations received a full-text review. Studies that contained case reports, procedures related to the atlantoaxial junction, discectomy, nucleotomy and laminoforaminotomy or foraminotomy with laminoplasty were excluded. The remaining 26 publications were used in this systematic review (Fig. 1).

There was one randomised controlled trial, two prospectively followed cohorts and 13 retrospective case series in the open group compared with one randomised controlled trial, two prospectively followed cohorts and seven retrospective case series in the microsurgery group. Descriptive information for each study is given in Tables 1 and 2.

Three publications were excluded because they did not reported the clinical success rate in the microsurgery group [20–22] compared with six publications in the open group [23–27], and one was excluded because it reported patients younger than 15 years ($n = 13$) in the open group [28].

Study heterogeneity

Statistical heterogeneity of the studies was performed by calculating effect indicators and standard errors (SE) based on clinical success rate. Statistical heterogeneity between studies was evaluated with the I^2 statistic. A Forest plot of the logit event rates demonstrated minimal to moderate heterogeneity, with an I^2 value of 27 % in the open group. There was also minimal heterogeneity in the microsurgery group, with I^2 value of 1 % (Figs. 2 and 3).

Blood loss, surgical time and hospital stay

Seven studies reported one or more peri-operative outcomes related to blood loss, surgical time and hospital stay in the open group compared with ten in the microsurgery group (Tables 3 and 4). Data aggregated from these reports found that patients treated by microsurgery foraminotomy have lower blood loss by 100.1 ml (open 149.5 ml, microsurgery 49.4 ml, $n = 1257$), shorter surgical time by 24.9 minutes (open 88.7 minutes, microsurgery 63.8 minutes, $n = 1423$) and shorter hospital stay by 3 days (open 4.1 days, microsurgery 1.1 days, $n = 1350$) compared with patients treated by open cervical foraminotomy (Figs. 4, 5 and 6).

Clinical success rate

Clinical success rates were reported in all studies. The pooled clinical success rate was 89.7 % (CI:87.7, 91.6) in the open group and 92.5 % (CI:89.9, 95.1) in the microsurgery group (Table 5); the difference was not statistically significant between groups ($p = 0.095$).

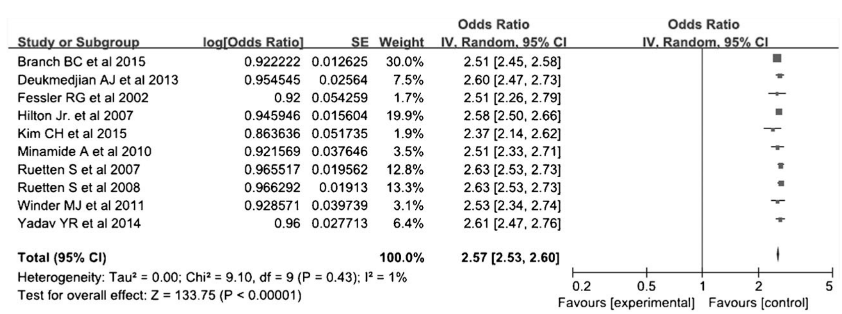

Fig. 3 Logit event rate by study in the microsurgery group

Table 3 Studies reporting blood loss, surgical time and hospital stay from open procedures

Study	No. patients	Blood Loss (ml)	Surgical time (min)	Hospital stay (days)
Kang et al. [2] 2014	18	169.7	95.7	9.5
Kim KT et al. [29],2009	19	NR	76.5	6.7
Holly LT et al. [30],2007	21	35	NR	0.7
Chang JC et al. [31],2011	34	50	37	3
Korinth MC et al. [32], 2006	168	NR	94.1	4.5
Winder MJ et al. [12],2011	65	233	103.3	2.4
Grieve JP et al. [33],2000	62	NR	NR	4

NR not reported

Complications

The pooled complications rate was 3.35 % (28/835) in the open group and 3.61 % (42/1163) in the microsurgery group. The difference in complication rate was not statistically significant between groups ($p = 0.757$, Pearson chi-square). The most common complications in either group were dural tears, nerve root injury and infection. Dural tears were an infrequent occurrence in both groups. Pooled dural tear rate amongst all microsurgery procedures in our review was 1.07 % (12/1121). Traditional open surgery had an overall 0.27 % (2/745) incidence ($p = 0.\ 091$, continuity correction). Continuity correction yielded $p = 0.091$, indicating weak evidence approaching significance for difference between microsurgery and open procedures. Overall rates of infection were low, only occurring in 0.54 % (6/1121) in the microsurgery group; the traditional open surgery had a 0.40 % (3/745) incidence ($p = 0.949$, continuity correction). Continuity correction yielded $p = 0.949$, indicating no significant difference in infection between microsurgery and open procedures. Nerve root injury occurred in 0.80 % (9/1121) of trials in the microsurgery group: Traditional open surgery had a 1.48 % (11/745) rate ($p = 0.166$, Pearson chi-square). Pearson chi-square yield $p = 0.166$, indicating no significant difference between groups.

Revision surgery

Revision surgery occurred in 2.32 % (27/1163) of trials in the microsurgery group, and traditional open surgery had a rate of 3.35 % (28/835) ($p = 0.164$, Pearson chi-square). Pearson chi-square yielded $p = 0.164$, indicating no significant difference in revision surgery between microsurgery and open procedures.

Reduction of VASA/VASN

Ten publications reported post-operative outcomes related to the reduction of arm and/or neck pain (VASA/VASN) in the open compared with six in the microsurgery group. Pooled VASA reduction was 75.0 % (CI:66..0, 84.0) in the open group and 87.1 % (CI:76.7, 97.5) in the microsurgery group (Table 6); the difference was not statistically significant between groups ($p = 0.065$).

Pooled reduction of VASN was 66.2 % (CI:52.2, 80.2) in the open and 68.1 % (CI:36.4, 99.8) in the microsurgery group

Table 4 Studies reporting blood loss, surgical time and hospital stay for microsurgery group

Study	No.	Blood Loss (ml)	Surgical time (min)	Hospital stay (days)
Ruetten S et al. [5],2008	100	5	28	NR
Winder MJ et al. [12],2011	42	96	100.7	1.12
Kim CH et al. [13],2015	44	NR	NR	1
Branch BC et al. [14],2015	463	59.5	59.7	0.51
Deukmedjian AJ et al. [15],2013	66	5	57	0.5
Minamide A et al. [34],2010	51	32.6	130.8	8.6
Fessler RG et al. [16],2002	25	138	115	0.83
Hilton Jr. et al. [17],2007	222	71	63	0.48
Yadav YR et al. [18],2014	50	30	135	2.2
Ruetten S et al. [19],2007	100	5	27	NR

NR not reported

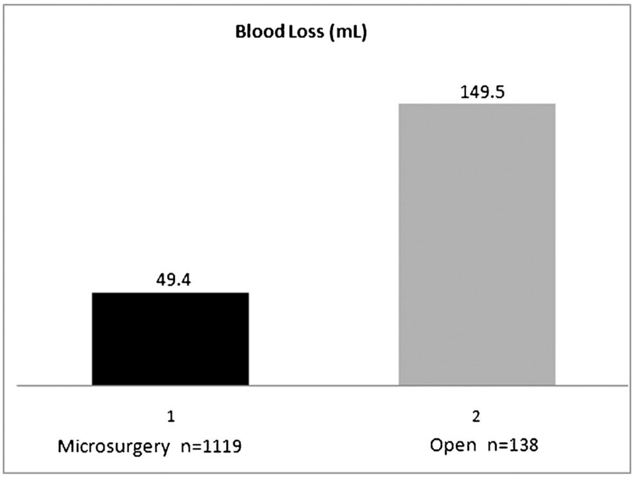

Fig. 4 Comparison of blood loss between microsurgery and open groups

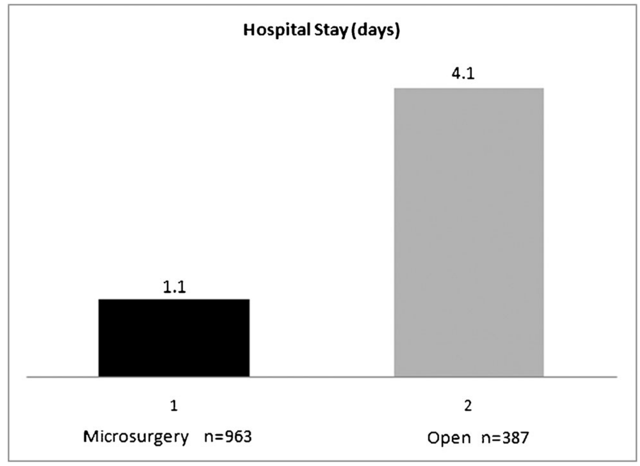

Fig. 6 Comparison of hospital stay between microsurgery and open groups

(Table 6). The difference in VASN reduction was not statistically significant ($p = 0.894$).

Improvement of neurological function

Five publications reported post-operative outcomes related to improvement in neurological function based on the NDI or the NASS in either group. Pooled improvement of neurological function was 55.3 % (CI:18.6, 91.9) in the open and 64.9 % (CI:34.6, 95.2) in the microsurgery group. The difference in improvement of neurological function was not statistically significant between groups ($p = 0.576$) (Table 6).

Discussion

Cervical foraminotomy is an effective treatment for symptomatic cervical radiculopathy. Though the traditional cervical open foraminotomy is a well-established technique for treating cervical radiculopathy, endoscopic surgical techniques, as an alternative to standard open approaches, change with each passing day, with reported outcomes equal to or better than those seen with traditional cervical open foraminotomy. The decision regarding approach and surgery type is based on patient- and surgeon-specific considerations. This systematic review was performed based on the single-effect indicator of clinical success rate. We identified 26 publications that reported peri-operative outcomes, including clinical success rate, from open ($n = 16$) and microendoscopic ($n = 10$) procedures. In the open group, there was minimal to moderate heterogeneity among studies, with an I^2 of 27. The microendoscopic group demonstrated minimal heterogeneity for clinical success, with an I^2 value of 1. It can thus be inferred that results from both open and microendoscopic groups possess good, consistent results, and the results reported are likely close to the true effect. Data aggregated from the published literature including blood loss, surgical time, hospital stay, clinical success rate, complications, reduction in VASA and VASN and improvement in neurological function were analysed and compared between microendoscopic and open procedures. To our knowledge, this is the first systematic review of these procedures.

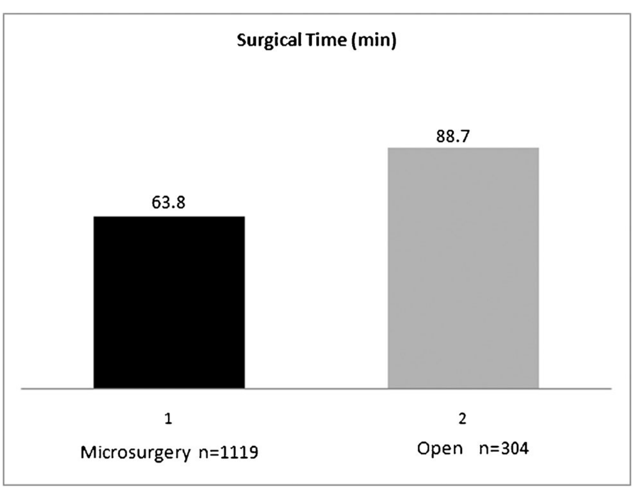

Fig. 5 Comparison of surgical time between microsurgery and open groups

A recent meta-analysis by Mcanany et al. [43] reported clinical outcomes and success of open foraminotomy versus MIS foraminotomy. They identified 20 studies that met inclusion criteria. The summative clinical success rate was 92.7 % for open and 94.9 % for MIS foraminotomy, which was not statistically significant ($p = 0.418$). In our systematic review, the pooled clinical success rate was 89.7 % in the open group and 92.5 % in the microsurgery group, which is slightly lower than the literature; however, the difference was not statistically significant between groups ($p = 0.095$). A recent systematic review by Clark et al. [44] reported results of open versus

Table 5 Effect of surgical technique via microsurgery or open cervical foraminotomy and clinical success

Open					Microsurgery				
Study	No.	Clinical success	95 % CI		95 % CI		Clinical success	No.	Study
			Lower	Upper	Upper	Lower			
Kang MS et al. [2]	16/18	0.889	0.665	0.986	0.993	0.910	0.966	86/89	Ruetten S et al. [5]
Park YK et al. [3]	47/50	0.940	0.844	0.987	0.985	0.815	0.929	39/42	Winder MJ et al. [12]
Jho HD et al. [35]	83/104	0.798	0.728	0.871	0.948	0.744	0.864	38/44	Kim CH et al. [13]
Kim KT et al. [29]	16/19	0.842	0.620	0.966	0.948	0.903	0.922	415/450	Branch BC et al. [14]
Cornelius JF et al. [36]	38/40	0.950	0.838	0.994	0.990	0.880	0.955	63/66	Deukmedjian AJ et al. [15]
Holly LT et al. [30]	19/21	0.905	0.710	0.988	0.978	0.823	0.922	47/51	Minamide A et al. [34]
Witzmann A et al. [37]	62/67	0.925	0.846	0.975	0.990	0.750	0.920	23/25	Fessler RG et al. [16]
Chang JC et al. [31]	29/34	0.853	0.706	0.951	0.892	0.799	0.847	188/222	Hilton Jr. et al. [17]
Korinth MC et al. [32]	142/168	0.845	0.791	0.896	0.995	0.869	0.960	48/50	Yadav YR et al. [18]
Skovrlj B et al. [38]	62/70	0.886	0.802	0.950	0.993	0.908	0.966	84/87	Ruetten S et al. [19]
Winder MJ et al. [12]	58/65	0.892	0.805	0.956					
Choi G et al. [30]	18/20	0.900	0.693	0.988					
Kotil Ket al [39]	23/25	0.920	0.750	0.990					
Saringer W et al. [40]	32/34	0.941	0.812	0.993					
Balasubramanian et al.[41]	32/34	0.941	0.812	0.993					
Grieve JP et al. [33]	51/62	0.823	0.724	0.908					
Choi G et al. [30]	18/20	0.900	0.693	0.988					

Ci confidence interval

percutaneous foraminotomy, identifying 19 studies that met inclusion criteria. Their systematic review reported that patients undergoing percutaneous cervical foraminotomy have lower blood loss, shorter surgical time and shorter hospital stay compared with patients undergoing open procedures. By comparison, our data aggregated in this systematic review

Table 6 Reduction of visual analogue scale for the arm (VASA) and neck (VASN) and improvement in neurological function via microsurgery or open cervical foraminotomy

Open				Microsurgery			
Study	Reduction of VASN	Reduction of VASA	Improvement of neurological function	Improvement of neurological function	Reduction of VASA	Reduction of VASN	Study
Kang MS et al. [2]	56.5 %	48.5 %	NR	50 %	91.7 %	5.9 %	Ruetten S et al. [5]
Park YK et al. [3]	53.7 %	72.7 %	57.7 %	86.3 %	87 %	86 %	Kim CH et al. [13]
Jho HD et al. [35]	66.9 %	66.9 %	13.5 %	NR	94.3 %	94.3 %	Deukmedjian et al. [15]
Kim KT et al. [29]	76.7 %	78.4 %	NR	NR	67.4 %	67.4 %	Minamide A et al. [34]
Witzmann A et al. [37]	71.6 %	71.6 %	NR	NR	92 %	87 %	Fessler RG et al. [16]
Chang JC et al. [31]	20.5 %	68.5 %	NR	64.6 %	NR	NR	Yadav YR et al. [18]
Skovrlj B et al. [38]	83.3 %	83.3 %	68.9 %	58.8 %	90.1 %	-20 %	Ruetten S et al. [19]
Choi G et al. [42]	65 %	92 %	92.8 %				
Kotil K et al. [39]	89.9 %	89.9 %	NR				
Balasubramanian et al. [41]	77.8 %	77.8 %	43.5 %				

NR not reported

found that patients undergoing microsurgery procedures have lower blood loss by 100.1 ml, shorter surgical time by 24.9 minutes and shorter hospital stay by 3.0 days. Similar results have been achieved, but the authors did not look specifically at the outcomes of clinical success, complications, reduction of VASA and VASN and improvement of neurological function. This difference accounts for the different number of studies included in our systematic review.

Specifically, the quality of available studies comparing complications and revision surgery between microendoscopic and open spinal surgeries limits this systematic review. Twelve of our studies were small, with 50 or fewer participants in each study arm, and four of our studies reported on the overall follow-up time <12 months. Most studies were cohorts, which can introduce selection bias, since it is possible that more complex cases prone to complications and revision surgery underwent either procedure. For example, Fessler et al. [16] reported that 25 patients treated with microendoscopic foraminotomy had no symptomatic recurrences of disc herniations or foraminal stenosis at the operated level within 4.6 months' follow-up. In order to accurately determine the rate of complications and revision surgery, large prospective trials are needed that account for both surgeon experience and patient comorbidity through random allocation or statistical controlling.

Meanwhile, we are aware that fewer results correlated with pain relief in microsurgery or open foraminotomy have been published. In addition, few of these studies take into account the improvement of neurological function. To analyse more fully, we included results on functional recovery in our systematic review. Particularly worth mentioning is the randomised clinical trial conducted by Ruetten et al. [10], which reported significant reduction in radicular pain symptoms ($P<0.001$) and the improvement in neurological function by 50 % based on the NASS score in the full-endoscopic group. However, reduction of neck pain was only 5.9 %, and more advancing degeneration in the disc (24 %) may be the reason for little reduction in neck pain in the full-endoscopic group.

This study is limited by the paucity of good, randomised controlled studies, and the heterogeneous nature of reported outcomes made strict meta-analysis impossible. It is important that more structured and thorough trials be designed to clarify the risks and benefits associated with each of these procedures.

Microsurgery has reduced blood loss and shorter surgical time and hospital stay as advantages over the standard open technique. However, there is no significant difference in clinical success rate, complication rate, reduction of arm and neck pain and improvement of neurological function between microsurgery and open cervical foraminotomy. Patients with symptomatic cervical radiculopathy can be effectively managed with either microsurgery or traditional open foraminotomy. The decision on approach and surgery type are based on both patient- and surgeon-specific considerations.

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