Anterior Cervical Discectomy and Fusion Versus Microendoscopic Posterior Cervical Foraminotomy for Unilateral Cervical Radiculopathy: A 1-Year Cost-Utility Analysis

Steve H. Monk, MD[*‡], Ummey Hani, MBBS[*‡], Deborah Pfortmiller, PhD, MA[*‡], E. Hunter Dyer, MD[*‡], Mark D. Smith, MD[*‡], Paul K. Kim, MD[*‡], Michael A. Bohl, MD[*‡], Domagoj Coric, MD[*‡], Tim E. Adamson, MD[*‡], Christopher M. Holland, MD, PhD[*‡], Matthew J. McGirt, MD[*‡]

*Carolina Neurosurgery & Spine Associates, Charlotte, North Carolina, USA; ‡SpineFirst, Atrium Health, Charlotte, North Carolina, USA

Correspondence: Steve H. Monk, MD, 225 Baldwin Ave, Charlotte, NC 28204, USA. Email: Steve.Monk@CNSA.com

Received, October 28, 2022; **Accepted,** January 26, 2023; **Published Online,** March 30, 2023.

BACKGROUND: Anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF) are the most common surgical approaches for medically refractory cervical radiculopathy. Rigorous cost-effectiveness studies comparing ACDF and PCF are lacking.

OBJECTIVE: To assess the cost-utility of ACDF vs PCF performed in the ambulatory surgery center setting for Medicare and privately insured patients at 1-year follow-up.

METHODS: A total of 323 patients who underwent 1-level ACDF (201) or PCF (122) at a single ambulatory surgery center were compared. Propensity matching generated 110 pairs (220 patients) for analysis. Demographic data, resource utilization, patient-reported outcome measures, and quality-adjusted life-years were assessed. Direct costs (1-year resource use × unit costs based on Medicare national allowable payment amounts) and indirect costs (missed workdays × average US daily wage) were recorded. Incremental cost-effectiveness ratios were calculated.

RESULTS: Perioperative safety, 90-day readmission, and 1-year reoperation rates were similar between groups. Both groups experienced significant improvements in all patient-reported outcome measures at 3 months that was maintained at 12 months. The ACDF cohort had a significantly higher preoperative Neck Disability Index and a significantly greater improvement in health-state utility (ie, quality-adjusted life-years gained) at 12 months. ACDF was associated with significantly higher total costs at 1 year for both Medicare ($11 744) and privately insured ($21 228) patients. The incremental cost-effectiveness ratio for ACDF was $184 654 and $333 774 for Medicare and privately insured patients, respectively, reflecting poor cost-utility.

CONCLUSION: Single-level ACDF may not be cost-effective in comparison with PCF for surgical management of unilateral cervical radiculopathy.

KEY WORDS: Ambulatory surgery center, Anterior cervical discectomy and fusion, Cost utility, Microendoscopic, Posterior cervical foraminotomy

Neurosurgery 93:628–635, 2023 https://doi.org/10.1227/neu.0000000000002464

Cervical radiculopathy is a common and debilitating disease.[1] Surgical intervention is required in the subset of patients whose symptoms fail to respond to nonoperative management. The 2 most common surgical approaches are anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF). Over the past few decades, there has been a rapid increase in the frequency of ACDFs performed in relation to PCF despite no significant differences in outcomes to support this practice.[2-10] This discrepancy exists despite significantly higher costs associated with ACDF.[11-15]

Ambulatory surgery centers (ASCs) have emerged as important facilities in the current paradigm shift to value-based health care. Their small scale and limited procedure selection allow for more

ABBREVIATIONS: ACDF, anterior cervical discectomy and fusion; **ASCs,** ambulatory surgery centers; **CPT,** Current Procedural Terminology; **EQ-5D,** EuroQol-5D; **EBL,** estimated blood loss; **GED,** graduate equivalency degree; **HS,** high school; **ICER,** incremental cost-effectiveness ratio; **NDI,** Neck Disability Index; **PCF,** posterior cervical foraminotomy; **PROM,** patient-reported outcome measures.

efficient care delivery and lower costs. Over the past 2 decades, numerous spine surgeries have transitioned to the ambulatory surgery setting as studies have demonstrated excellent safety and similar or improved clinical outcomes.[16] For instance, the percentage of PCFs performed in the ASC setting grew from 0% in 2003 to 24% in 2014.[16] Although ACDF has been much slower to transition to the ambulatory setting, recent high-quality studies support the safety, efficacy, and cost-effectiveness of ambulatory ACDF.[17-20]

Rigorous cost-effectiveness studies comparing ACDF with PCF are lacking. The few studies in the literature are compromised by small sample size and selection bias.[12-14] Although PCF has frequently been associated with lower costs, it is unclear whether this is solely due to differences in surgical setting and hospital length of stay.[15] In addition, there are no studies to date that examine cost-effectiveness specifically in the ASC setting. The goal of this study was to perform the first cost-utility analysis of patients undergoing single-level ACDF or PCF in the ASC setting.

METHODS

Patient Selection

All consecutive patients undergoing single-level ACDF or PCF at a single ASC from 2012 to 2022 were queried. The operating surgeons belong to an institution at which ambulatory surgery is the standard of care for eligible patients. All patients were enrolled in the national Quality Outcomes Database.[21] All patients were American Society of Anesthesiologists (ASA) class I-III. Exclusion criteria included age less than 18 years and non-degenerative pathology. A total of 323 patients met inclusion criteria (201 ACDF and 122 PCF). Propensity score matching was then performed to reduce the effects of confounding variables. Propensity scores were estimated using a logistic regression model that included age, body mass index, sex, ASA score, and preoperative patient-reported outcome measures (PROMs). This resulted in 220 patients (110 ACDF and 110 PCF) for analysis. Approval was obtained from the Atrium Health Institutional Review Board Institutional Review Board with waiver of informed consent.

Surgical Technique

ACDFs were performed in standard fashion. All PCFs were performed using a microendoscopic technique.[22] This muscle-splitting approach uses a tubular retractor system in conjunction with an endoscope to minimize tissue disruption and blood loss, thereby lessening postoperative pain and facilitating same-day discharge.

Demographic and Clinical Data

Demographic data, comorbidities, and relevant clinical history were prospectively collected for all patients. Perioperative safety and healthcare utilization data, 90-day readmission, and 1-year reoperation rates were prospectively collected. Analyses were performed post hoc.

PROMs

PROMs were prospectively collected via patient questionnaires at the preoperative, 3-month, and 1-year postoperative patient interviews. This was done via email or interviews conducted by full-time research employees. These included the Visual Analog Scale for neck and arm pain, Neck Disability Index, and EuroQol-5D (EQ-5D) for health-state utility (quality-adjusted life-years [QALYs]). The EQ-5D is a validated, reliable instrument that assesses preference-based health-state utility over 5 dimensions.[23] Responses are converted into a single index value. Cumulative improvement in EQ-5D over the 1-year follow-up period provided an estimate of QALYs gained in each group.

Direct and Indirect Costs

Direct costs included facility and professional fees for the index surgery and reoperation (if applicable) and hospital readmission costs. The 2021 Medicare Current Procedural Terminology (CPT)–based ASC facility fee schedule was used to estimate ASC-related facility costs. The 2021 Medicare CPT-based professional fee schedule was used to estimate professional fees. For Medicare beneficiaries, costs were estimated using published allowable amounts. Costs for patients with private insurance were estimated at twice the Medicare allowable amount for equivalent services.[24] This estimate is based on data demonstrating that private insurers pay double (199%) Medicare rates for all hospital services, ranging from 141% to 259%.[25-31] All direct costs were inflation-adjusted and discounted using 2021 as the base year.

Indirect costs were estimated using lost earnings during the postoperative period. Return to work was defined as the number of days from the date of surgery until the first day back at work. The number of missed workdays was multiplied by the current average daily earnings of US employees to estimate total lost earnings.[32] The total estimated 1-year cost was defined as the sum of all direct and indirect costs. Retired and unemployed patients did not have an indirect cost assigned.

Cost-Utility Analysis

The incremental cost-effectiveness ratio (ICER) was calculated to estimate the cost per additional QALY gained using the following formula:

$$\text{ICER} = \text{Total cost}_{\text{ACDF}} - \text{Total cost}_{\text{PCF}} / \text{QALY gained}_{\text{ACDF}} - \text{QALY gained}_{\text{PCF}}$$

Sensitivity Analysis

A formal sensitivity analysis was undertaken to assess the robustness of the cost-utility results to variations of key variables. This was performed by a bootstrap method using 1000 samples taken with replacement from the propensity-matched cohort.[33]

Statistical Analysis

All statistical analyses were performed using SPSS v27 (IBM). Univariate parametric data are reported as mean ± SD, and nonparametric data are reported as frequency (%). Bivariate analyses were conducted using independent *t*-tests and χ^2 tests, as appropriate. General linear model repeated measures were used to examine group interactions between the cohorts and PROMs over time. Statistical significance was defined as $P < .05$.

RESULTS

Descriptive Data

Total Cohort

Table 1 reports the demographic data for the entire patient population. There was a significantly higher percentage of male (54.9% vs 43.3%, $P = .042$) and Hispanic/Latino patients (5.2% vs

TABLE 1. Total Population Demographics and Clinical History

Variable	ACDF	PCF	*P* value
N	201	122	
Demographics			
Age, y (mean ± SD)	53.0 ± 9.8	53.0 ± 11.1	0.930
BMI (mean ± SD)	29.4 ± 5.4	28.6 ± 5.2	0.181
Male	43.3%	54.9%	0.042[a]
Race			
White	90.9%	88.0%	0.672
Black	8.1%	11.1%	
Other	1.0%	0.9%	
Hispanic/Latino	0.5%	5.2%	0.008[a]
Payer			
Private	80.1%	79.5%	0.185
Medicare	15.4%	11.5%	
Other	4.5%	9.0%	
Employed	69.6%	73.0%	0.115
Education			
≤HS graduation/GED	31.2%	35.5%	0.338
2-4 years of college	53.8%	45.5%	
Postcollege	15.1%	19.0%	
Comorbidities			
Smoker	18.3%	7.4%	0.007[a]
Diabetes	13.9%	10.7%	0.391
Depression	14.9%	11.5%	0.381
Anxiety	10.9%	11.5%	0.883
Osteoporosis	0.5%	2.5%	0.122
ASA			
1	16.4%	19.7%	0.589
2	68.7%	63.1%	
3	14.9%	17.2%	

ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists; BMI, body mass index; GED, graduate equivalency degree; HS, high school; PCF, posterior cervical foraminotomy.
[a]Significant at $P < .05$.

0.5%, $P = .008$) in the PCF cohort. Patients in the ACDF cohort were significantly more likely to be smokers (18.3% vs 7.4%, $P = .007$). No other statistically significant baseline differences existed between groups.

Matched Cohort

Propensity score matching yielded 220 patients (110 ACDF and 110 PCF) for analysis. Table 2 shows the demographic and clinical data for the matched pairs. The percentage of Hispanic/Latino patients remained significantly higher in the PCF cohort (3.9% vs 0%, $P = .050$). Anxiety was twice as common in the PCF cohort (12.7% vs 5.5%, $P = .061$), and osteoporosis was 3 times as common in the PCF cohort (2.7% vs 0.9%, $P = .313$). Diabetes was slightly more common in the ACDF cohort (14.5% vs 11.8%, $P = .550$).

Outcome Data

Perioperative Data

Perioperative data are shown in Table 3. Estimated blood loss (26.9 vs 14.9 cc, $P < .001$) and length of surgery (61.2 vs 41.3 min, $P < .001$) were significantly higher in the ACDF group. All patients were discharged home on the day of surgery. The 90-day readmission rate was 3 times higher in the ACDF group (2.7% vs 0.9%, $P = .313$). Reoperation rate was low and identical between groups.

PROMs

Figures 1A-D represent the mean PROM scores at preoperative, 3-month, and 12-month follow-up interviews. There was a significant improvement from the preoperative to the 3-month follow-up interview across all PROMs in both cohorts, which was maintained at 12 months (all significant at $P < .001$). The only significant difference between groups was a higher preoperative NDI in the ACDF cohort compared with the PCF cohort (39.75 ± 16.6 vs 35.09 ± 16.2, $P = .036$). There was a trend toward a higher health-state utility at 12 months postoperatively in the ACDF cohort (0.84 ± 0.2 vs 0.80 ± 0.2, $P = .096$). Cumulative improvement in health-state utility (ie, QALYs gained) at 12 months was significantly greater in the ACDF cohort (0.18 ± 0.2 vs 0.11 ± 0.2, $P = .010$).

Patient Satisfaction

Figure 1E shows patient satisfaction with surgical outcomes at 3 and 12 months postoperatively. Patient satisfaction was greater than 80% at both times point across both cohorts. There were no significant differences between groups at either time point.

Return to Work

The cumulative distribution function curve in Figure 2 demonstrates the return to work rate. The majority (95.8% ACDF and 95.2% PCF) of employed patients in both groups returned to work within 3 months of surgery. Median time to return to work was significantly shorter in the PCF cohort (2.4 ± 0.4 vs 4.4 ± 0.2 weeks, $P = .036$).

Main Results

Cost-Utility Analysis

Tables 4 and 5 demonstrate the cost-utility analysis for Medicare and privately insured patients, respectively. Estimated

TABLE 2. Propensity-Matched Population Demographics and Clinical History

Variable	ACDF	PCF	*P* value
N	110	110	
Demographics			
Age, y (mean ± SD)	52 ± 9.6	53 ± 11.0	.754
BMI (mean ± SD)	29.3 ± 4.8	28.4 ± 5.3	.194
Male	54.5%	51.8%	.685
Race			
White	89.8%	87.7%	.661
Black	8.3%	11.3%	
Other	1.9%	0.9%	
Hispanic/Latino	0%	3.9%	.050
Payer			
Private	82.7%	80.9%	.718
Medicare	11.8%	10.9%	
Other	5.5%	8.2%	
Employed	72.7%	73.6%	.879
Education			
≤HS graduation/GED	31.2%	33.0%	.772
2-4 years of college	52.3%	47.7%	
Postcollege	16.5%	19.3%	
Comorbidities			
Smoker	7.3%	6.4%	.789
Diabetes	14.5%	11.8%	.550
Depression	11.8%	11.8%	1.000
Anxiety	5.5%	12.7%	.061
Osteoporosis	0.9%	2.7%	.313
ASA			
1	20.9%	20.0%	.844
2	66.4%	64.5%	
3	12.7%	15.5%	

ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists; BMI, body mass index; PCF, posterior cervical foraminotomy.

TABLE 3. Propensity-Matched Facility Utilization

Variable	ACDF	PCF	*P* value
EBL, cc (mean ± SD)	26.9 ± 11.8	14.9 ± 9.6	<.001[a]
Length of surgery, min (mean ± SD)	61.2 ± 26.3	42.3 ± 22.4	<.001[a]
Discharge home	100%	100%	—
Readmission within 90 d	2.7%	0.9%	.313
Reoperation within 1 y	0.9%	0.9%	1.000

ACDF, anterior cervical discectomy and fusion; EBL, estimated blood loss; PCF, posterior cervical foraminotomy.
[a]Significant at $P < .05$.

direct costs were significantly higher for the ACDF cohort regardless of insurance status. Indirect costs were similar between cohorts. QALYs gained was significantly greater in the ACDF cohort, with a 1-year QALY gained difference of 0.0636 favoring the ACDF cohort. The ICER of ACDF vs PCF was $184 654 (95% CI: $23 287-$525 594) for Medicare patients and $333 774 (95% CI: $33 860-$751 272) for privately insured patients.

DISCUSSION

Key Results

In this large propensity-matched study of ASA class I-III patients undergoing 1-level ACDF or PCF for unilateral cervical radiculopathy in the ASC setting, we found a mean increased cost of $11 744 and $21 228 associated with ACDF for Medicare and privately insured patients, respectively. Importantly, indirect costs were similar between groups, which suggests that direct costs related to facility and professional fees were the main drivers of this disparity. The higher rate of 90-day readmission in the ACDF group likely also contributed to this cost difference. Despite higher costs, there was a small but significant QALY benefit associated with ACDF. The ICER for ACDF was $184 654 for Medicare patients and $333 774 for privately insured patients, suggesting poor cost-utility.

Interpretation

ACDF has long been the gold standard operation for medically refractory cervical radiculopathy. Despite the low morbidity and predictably good outcomes associated with the procedure, concerns regarding long-term adjacent segment disease and need for adjacent level reoperation have spurred interest in motion-sparing alternatives.[34] PCF has been shown to have equivalent clinical outcomes and complication rates in comparison with ACDF.[3-10] Although PCF is thought to limit adjacent-level stress and, by extension, decrease rates of adjacent-level reoperation, most studies report similar rates of reoperation after ACDF and PCF.[8,10,35,36]

In addition to its motion-sparing nature, PCF is an attractive alternative to ACDF because of potential cost savings. Multiple studies using nationwide administrative databases have demonstrated significantly higher costs associated with ACDF vs PCF.[11,15] Although such studies are important, their results are not surprising

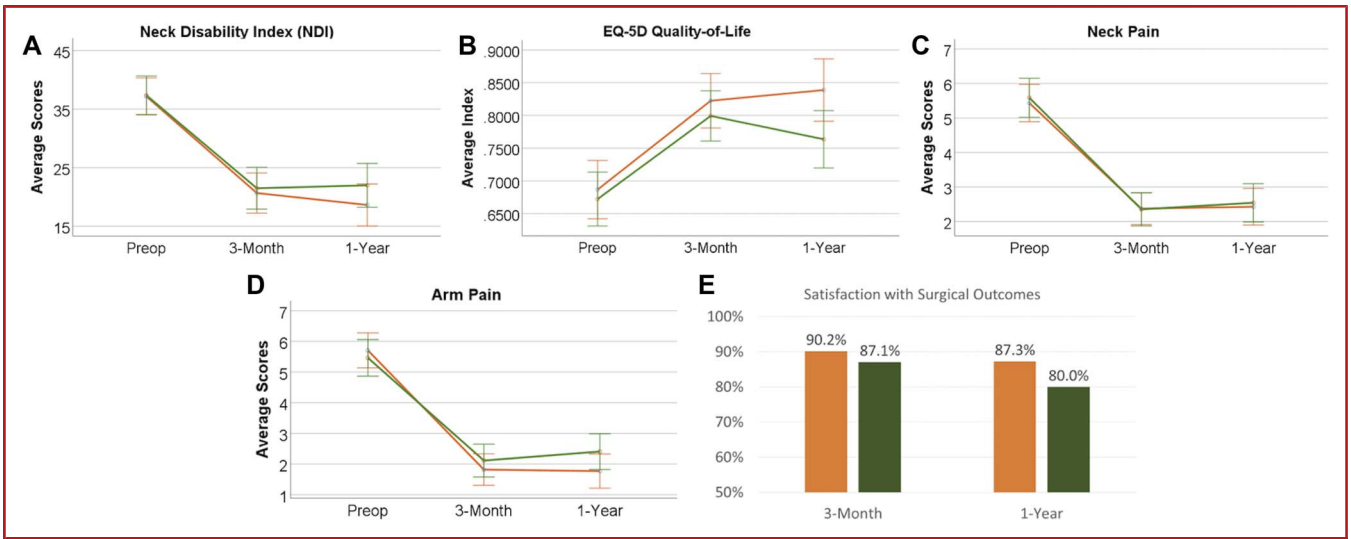

FIGURE 1. *A, NDI scores were significantly improved at 3 months postoperatively and maintained at 12 months. Preoperative NDI was significantly higher in the ACDF cohort than in the PCF cohort. Values were similar at 3 and 12 months. B, Both groups experienced a significant gain in quality of life 3 months postoperatively that was maintained at 12 months. Quality of life was higher in the ACDF cohort than in the PCF cohort at 12 months but did not reach statistical significance. C, VAS neck pain scores were significantly improved at 3 months postoperatively and maintained at 12 months. There were no differences between groups at any time point. D, VAS arm pain scores were significantly improved at 3 months postoperatively and maintained at 12 months. There were no differences between groups at any time point. E, Patient satisfaction scores were similar between groups at 3 and 12 months. ACDF labeled in orange; PCF labeled in green. ACDF, anterior cervical discectomy and fusion; EQ-5D, EuroQol-5D; NDI, Neck Disability Index; PCF, posterior cervical foraminotomy; VAS, Visual Analog Scale.*

and do not provide granular data that can guide public policy. Cost-effectiveness studies are necessary to estimate the value of competing interventions by simultaneously comparing outcomes and costs. To date, only 3 such studies exist in the literature, all of which report PCF as cost-effective in comparison with ACDF.[12-14] It is important to note, however, that only 1 of these studies performed rigorous cost-utility analysis and reported an ICER.[12] In their study of 70 unmatched patients (45 ACDF and 25 PCF), Alvin et al[12] demonstrated greater QALY gained and lower costs at 1 year after PCF vs ACDF, rendering PCF health economically dominant to ACDF. This study thus represents the largest cost-utility analysis of ACDF vs PCF for unilateral cervical radiculopathy and the first performed in the ASC setting.

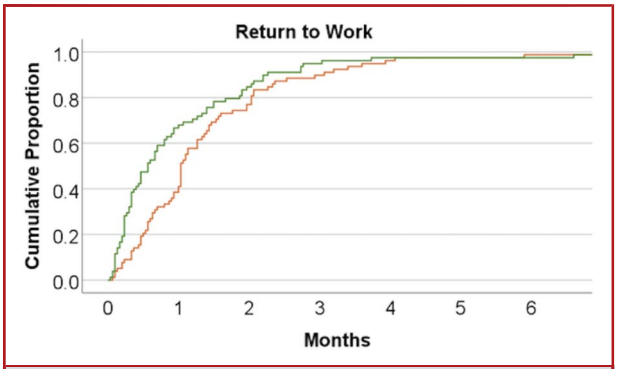

FIGURE 2. *Cumulative distribution function curve shows a significantly shorter median time to return to work in the posterior cervical foraminotomy cohort.*

The significant improvement in health-state utility seen in the ACDF cohort was surprising, given the clinical equipoise between ACDF and PCF for treatment of unilateral cervical radiculopathy. There are several possible explanations. Preoperative NDI was higher in the ACDF cohort despite similar neck pain scores between groups. It logically stands to reason that patients with higher baseline disability would experience greater health-state improvements after appropriate treatment. In addition, there was a significantly higher percentage of Hispanic/Latino patients in the PCF cohort, along with more than double the percentage of patients with anxiety. Both of these variables have been associated with worse outcomes after cervical spine surgery and could contribute to the disparity in QALY gain between cohorts.[37,38]

The ICER reflects the incremental cost necessary to procure an incremental effect from a given intervention (in this case, 1 additional QALY). If the calculated value is above a maximum threshold of willingness to pay, then the given intervention is not cost-effective. Considerable debate exists regarding the optimal threshold.[39,40] A standard $50 000 threshold has been widely cited in the United States but is considered highly controversial, with experts more recently recommending a threshold of $100 000 to 150 000.[41,42] Some authors recommend even higher thresholds of $200 000.[43,44] The World Health Organization's Choosing Interventions that are Cost-Effective program recommends a threshold of less than 3 times the national annual gross domestic product per capita, which equates to $175 434 in the United States.[45,46]

TABLE 4. Cost-Utility Analysis for Medicare Patients

Variable	ACDF	PCF	*P* value
	Mean ± SD	Mean ± SD	
Direct cost	$27 614 ± 12 660	$17 842 ± 12 183	<.001[a]
Indirect cost	$8016 ± 10 142	$6045 ± 10 830	.165
Total cost	$35 631 ± 16 980	$23 887 ± 16 721	<.001[a]
Total cost difference (ACDF−PCF)	$11 744		
QALY gained difference (ACDF−PCF)	0.0636		
ICER (95% CI)	$184 654 ($23 287-$525 594)		

[a]Significant at $P < .05$.

The results of this study suggest that ACDF is not cost-effective for surgical management of unilateral cervical radiculopathy. Even in the most favorable economic circumstances (ie, Medicare patients in a freestanding ASC), the ICER is near the reported thresholds for cost-effectiveness. The ICER becomes unacceptably high when comparing patients with private insurance in the ASC setting. The cost-utility of ACDF is likely even poorer when national practice patterns are considered. Despite the recent migration of spine surgeries to the ASC setting, ACDF is still performed primarily in the hospital setting. On the contrary, PCF is much more commonly performed in ASCs. The significant difference in facility fees between these settings would render ACDF even less cost-effective than reported in this study.[19]

Limitations

The authors acknowledge several limitations to the cost methodology. First, the inability to perform microcosting is a notable limitation of our study. Unit costs for outpatient visits and procedures during the follow-up period were not included. However, given the similar neck and arm pain scores at 3 and 12 months after surgery, we would not expect a significant difference in pain management utilization between groups. Second, professional fees were estimated using published CPT reimbursement rates from 2021 as opposed to the year of surgery. Because professional fees for ACDF and PCF have historically increased at similar rates, it is unlikely that this costing method significantly affected the results of this study. Third, work loss estimates were calculated using national wage averages as opposed to state-specific averages. We acknowledge that numerous patient-specific factors (eg, state of employment, job type, etc.) can produce variability in work loss estimates. However, these estimates typically project costs for an "average" person without attempting to capture these varying patient-specific factors. Finally, indirect costs were not assigned for retired or unemployed individuals. The rate of employment was similar between groups, so this limitation is unlikely to have significantly affected our results.

This study did not evaluate cost-utility beyond 1 year from surgery. Future studies are necessary to examine cost-utility of ACDF vs PCF in the long term. This is especially important considering possible differences in reoperation rates between groups that may not manifest until years after surgery.

TABLE 5. Cost-Utility Analysis for Privately Insured Patients

Variable	ACDF	PCF	*P* value
	Mean ± SD	Mean ± SD	
Direct cost	$54 327 ± 23 677	$35 070 ± 21 423	<.001[a]
Indirect cost	$8016 ± 10 142	$6045 ± 10 830	.165
Total cost	$62 343 ± 26 882	$41 115 ± 24 709	<.00[a]
Total cost difference (ACDF−PCF)	$21 228		
QALY gained difference (ACDF−PCF)	0.0636		
ICER	$333 774 ($33 860-$751 272)		

ACDF, anterior cervical discectomy and fusion; ICER, incremental cost-effectiveness ratios; PCF, posterior cervical foraminotomy; QALY, quality-adjusted life-years.
[a]Significant at $P < .05$.

Generalizability

Our results are generalizable to all surgeons who treat cervical radiculopathy with ACDF and PCF. Surgeons who rarely perform PCF or use alternative techniques (ie, open instead of microendoscopic) may not experience the results reported in this study.

CONCLUSION

Single-level ACDF for unilateral cervical radiculopathy may not be cost-effective in comparison with PCF. A small but significant improvement in QALYs 1 year after surgery is offset by significantly higher costs. PCF should be considered a first-line surgical option for unilateral cervical radiculopathy in appropriately selected patients.

Funding

This study did not receive any funding or financial support.

Disclosures

Mark D. Smith has a consulting agreement with Spinewave. Michael A. Bohl has financial relationships with SpineWave, Mirus, and SurgiStud/Dignity Health. Domagoj Coric has financial relationships with Medtronic, SpineWave, and Globus Medical. The other authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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