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Original Article

Cost analysis comparison between anterior and posterior cervical spine approaches

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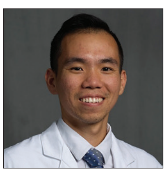

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ABSTRACT

Background: The costs of cervical spine surgery have steadily increased. We performed a 5-year propensity scoring-matched analysis of 276 patients undergoing anterior versus posterior cervical surgery at one institution.

Methods: We performed propensity score matching on financial data from 276 patients undergoing 1–3 level anterior versus posterior cervical fusions for degenerative disease (2015–2019).

Results: We found no significant difference between anterior versus posterior approaches for hospital costs ($42,529.63 vs. $45,110.52), net revenue ($40,877.25 vs. $34,036.01), or contribution margins ($14,230.19 vs. $6,312.54). Multivariate regression analysis showed variables significantly associated with the lower contribution margins included age ($\beta = -392.3$) and length of stay (LOS; $\beta = -1151$). Removing age/LOS from the analysis, contribution margins were significantly higher for the anterior versus posterior approach ($17,824.16 vs. $6,312.54, $P = 0.01$).

Conclusion: Anterior cervical surgery produced higher contribution margins compared to posterior approaches, most likely because posterior surgery was typically performed in older patients requiring longer LOS.

Keywords: Anterior, Cervical spine surgery, Contribution margins, Finances, Posterior, Propensity scoring matched analysis, Revenue

INTRODUCTION

Although comparisons between anterior and posterior cervical surgical approaches due to degenerative disease have been described in the literature, few studies have focused on relative costs.[3,4,6,8] Furthermore, few reports have investigated the revenue, profit, or contribution margins of either anterior or posterior cervical approaches. Here, we have performed a financial analysis of anterior versus posterior cervical surgical data coming from one institution over a 5-year period (2015–2019).

Table 1: Summary of patient demographics and outcomes for anterior and posterior approaches to cervical spine surgery before and after propensity score matching. Propensity score matching was performed using following variables: age, sex, race, levels, myelopathy, radiculopathy, LOS, and ASA.

Approach	Unmatched			Matched		
	Anterior (*n*=223)	Posterior (*n*=53)	*P*-value	Anterior (*n*=53)	Posterior (*n*=53)	*P*-value
Age (years)	57.4±12.4	65.1±13.3	**<0.01**	63.8±11.5	65.1±13.3	0.60
ASA	2.6±0.6	2.9±0.5	**<0.01**	2.9±0.5	2.9±0.5	0.56
Sex						
Female	43.9%	22.7%	**<0.01**	26.4%	22.7%	0.82
Male	56.1%	77.3%		73.6%	77.3%	
Ethnicity						
White	78.0%	77.4%	0.92	86.8%	77.4%	0.31
Other	22.0%	22.6%		13.2%	22.6%	
Myelopathic?						
Yes	73.1%	79.2%	0.37	77.4%	79.2%	>0.99
No	26.9%	20.8%		22.6%	20.8%	
Follow-up (years)	1.1±1.2	0.8±0.9	**0.04**	1.0±1.2	0.8±0.9	0.19
Number of Levels	1.6±0.6	2.1±0.9	**<0.01**	1.8±0.7	2.1±0.9	0.18
OR Time (hours)	4.2±1.1	4.7±1.3	0.76	4.8±1.4	4.7±1.3	0.53
Length of Stay (days)	2.1±2.2	4.5±3.9	**<0.01**	3.5±3.7	4.5±3.9	0.17

LOS: Length of stay, ASA: American Society of Anesthesiologists, *P*-value obtained with unpaired t-test

Table 2: Study guidelines.

Guideline	Description
CHEERS	Consolidated Health Economic Evaluation Reporting Standards
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

MATERIALS AND METHODS

We analyzed the demographic and financial data for 276 patients undergoing anterior (223 patients) versus posterior (53 patients) 1–3 level cervical fusions for spondylosis between 2015 and 2019; circumferential approaches were excluded from the study [Table 1]. The following variables were collected: American Society of Anesthesiologists (ASA) score, age, gender, ethnicity, spinal levels, operating room (OR) minutes, estimated blood loss, myelopathy, radiculopathy, time of the past follow-up, and length of stay (LOS). Financial variables included: total charges, total costs, net revenue, and contribution margins (direct cost subtracted from net revenue). Follow-up was performed utilizing chart reviews. To perform this study, we used multiple guidelines following IRB approval [Table 2].

Statistical analysis

The following statistical tests/analyses were utilized in this study: the unpaired *t*-test, Chi-squared analysis, and propensity scoring for matched cohorts (i.e., including assessment of multiple variables). Stata (StataCorp) was used for propensity score matched analysis, mean, and standard deviations [Table 1].

RESULTS

There was no significant difference between the two cohorts regarding: age, ASA score, gender, and LOS. The length of stay was over twice as long for the posterior group versus the anterior (4.5 vs. 2.1, $P < 0.01$). The number of levels involved was significantly higher in the posterior versus the anterior group (2.1 vs. 1.6, $P < 0.01$). Summary of the key findings for cost of anterior and posterior cervical spine surgical procedures are presented [Table 6].

Propensity score matching

Utilizing propensity score matching, (i.e., note the original data showed many more anterior [223] than posterior [53] surgical patients), there were 53 patients placed in each group [Tables 3 and 4]. For these two groups, there were no significant differences in hospital costs ($42,529.63 vs. $45,110.52), net revenue ($40,877.25 vs. $34,036.01), or contribution margins ($14,230.19 vs. $6,312.54). However, multivariate regression analysis with matched data showed that variables significantly associated with the lower contribution margins were age ($\beta = -392.3$) and LOS ($\beta = -1151$) [Table 5]. Nevertheless, after removing age and LOS from the propensity score matched analysis, there was still no significant difference in hospital costs ($38,816.83 vs. $45,110.52) or net revenue ($42,255.27 vs. $34,036.01), but contribution margins were significantly higher in the anterior versus posterior cohorts ($17,824.16 vs. $6,312.54).

Table 3: Propensity scoring matched analysis comparing anterior and posterior approaches controlling for the following variables: age, sex, race, levels, myelopathy, radiculopathy, LOS, and ASA.

	Anterior (*n*=53)	Posterior (*n*=53)	*P*-value
Total Charges	$159,909.50±$75,006.64	$179,924.28±$98,007.72	0.24
Total Costs	$42,529.63±$19,201.27	$45,110.52±$26,971.14	0.57
Net Revenue	$40,877.25±$28,019.60	$34,036.01±$15,565.69	0.12
Contribution Margin	$14,230.19±$27,976.92	$6,312.54±$15,740.02	0.08

LOS: Length of stay, ASA: American Society of Anesthesiologists

Table 4: Propensity scoring matched analysis comparing anterior and posterior approaches controlling for the following variables: sex, race, levels, myelopathy, radiculopathy, and ASA. Variables significantly different among cohorts (Age and LOS) have been removed.

	Anterior (*n*=53)	Posterior (*n*=53)	*P*-value
Total Charges	$151,020.84±$69,388.52	$179,924.28±$98,007.72	0.08
Total Costs	$38,816.83±$18,620.67	$45,110.52±$26,971.14	0.17
Net Revenue	$42,255.27±$26,812.70	$34,036.01±$15,565.69	0.57
Contribution Margin	$17,824.16±$27,531.58	$6,312.54±$15,740.02	**0.01**

LOS: Length of stay, ASA: American Society of Anesthesiologists, *P*-value obtained with unpaired t-test

Table 5: Multivariate regression analysis with matched data to determine which variables were significantly associated with lower contribution margins.

Variable	β Estimate	95% CI (asymptotic)	*P*-value
Approach	−9081	−16122–−2040	**0.012**
Age	134.9	−640.7–−105.1	**0.007**
Sex	3973	−7693–8081	0.961
Race	4208	−14145–2562	0.172
Levels	2191	−5451–3247	0.616
Myelopathy	4774	−3775–15178	0.235
Radiculopathy	3838	−7340–7899	0.942
ASA	973.6	−2373–1492	0.652
LOS	463.0	−2014–−176.2	**0.020**

Reference: Approach (anterior), sex (male), race (white), myelopathy (yes), radiculopathy (yes). LOS: Length of stay, ASA: American Society of Anesthesiologists, P-value obtained with unpaired t-test

DISCUSSION

This single-institution propensity score-matched analysis compared financial data in anterior and posterior spine surgery over 5 years. We found no significant differences in total charges, costs, net revenue, or contribution margins between anterior and posterior approaches. However, after removal of variables associated with the lower contribution margins on multivariate analysis (age and LOS), the anterior group had significantly higher contribution margins than the posterior group ($17,824.16 vs. $6,312.54, P = 0.01). These findings suggest that the lower contribution margins seen in posterior approaches were caused by an older patient population and longer hospital stay. Here, the authors, along with those from many other studies concluded that the decision to perform anterior versus posterior surgery must be made on a case-by-case basis.[6,9,13]

Financial parameters

Financial parameters include costs and charges to the patient and hospital, revenue, and contribution margins. While several studies found lower hospital charges and total payments in anterior approaches,[2,4,7,11,12] few prior studies have demonstrated significant associations between surgical approach and contribution margins. We found no significant differences in hospital charges or net revenue, but there were significantly higher contribution margins with anterior approaches after age and LOS were removed from propensity score matching; our results suggest that age and LOS raise variable costs, thereby lowering contribution margins. Advanced age is also associated with a higher comorbidity burden,[1] resulting in a multifactorial increase in variable costs.

Higher costs of posterior cervical fusions

An association between longer LOS and increased costs was observed after posterior cervical surgery in several studies. A study from Washington found posterior fusions had higher total hospital charges ($23,400 vs. $14,300) and longer LOS (4.6 vs. 3.8 days) compared to anterior fusions.[7] This relationship was echoed in a National Inpatient Sample study in which higher in-hospital charges ($99,841 vs. $59,934, $P < 0.001$) and a longer LOS (6.5 vs. 4.3 days, $P < 0.001$) were observed for posterior versus anterior cervical procedures.[12] A propensity score matched analysis also determined that posterior procedures had longer LOS (3.8 vs. 2.3 days),

Table 6 : Summary of key findings of clinical studies pertaining to costs of anterior versus posterior cervical spine surgery.

Author/Year	Study Design	Objective/Comparison	Sample Size	Key Findings	Level of Evidence
Agarwal *et al.* 2021[1]	Pros Cohort	Assess effect of preoperative frailty (using *RAI) on postoperative outcomes in spine surgery	668 Nonfrail: 510 Frail: 158	Compared to nonfrail patients, frail patients had: - [b]Longer LOS (3.9 vs. 3.1) - [a]Higher 60 (14.6% vs. 8.2%) and 90 d (15.8% vs. 9.8%) readmission rates	2
Boakye *et al.* 2008[2]	Retro Cohort - Database (NIS)	Describe inpatient mortality, complications, and outcomes after spinal fusion for CSM	58,115 A: 46,562 P: 8,112	[†]Compared to P, A procedures had: - Shorter LOS (3.4 vs. 5.7) - Lower charges ($23,209 vs. $30,927) - Lower complication rate (11.9% vs. 16.4%) - [†]1 post-op complication led to 4-d increase in LOS and $16,577 increase in hospital charges - [c]Patients with ≥3 comorbidities more likely to have a complication (OR 1.98)	3
Cole *et al.* 2015[4]	Retro Cohort - Databse (Market-Scan)	Compare rates of adverse events, revisions, and financial variables in≥3 level A versus *P* fusion procedures using propensity score matching	7,412 A: 4,895 P: 2,517	Compared to A, P procedures had: - [c]Lower post-op dysphagia rate (1.4% vs. 6.4%) - [c]Higher rate of all other post-op complications (17.8% vs. 12.3%) - Slightly higher overall complication rate (18.6% vs. 16.6%) - [b]Longer LOS (3.8 vs. 2.3d) - [c]Higher revision rate (18.1% vs. 12.8%) - [c]Higher readmission rate (9.9% vs. 5.1%) - [†]Higher hospital (+$5,292) and total (+$4,563) payments - [†]Lower physician payments (−$610)	3
Kalakoti *et al.* 2019[5]	Retro Series - Database (NIS)	Determine factors influencing hospitalization costs and LOS in patients undergoing ACDF	134,088	- [b]Patients with any comorbidity had longer LOS (1.85 vs. 1.32d) - [c]Adding posterior fusion had 1 day longer LOS - [b]Higher hospital costs in Western US (+$9,300)	4
King *et al.* 2009[7]	Retro Cohort - Database (WA)	Compare outcomes in surgery for degenerative cervical spine disease based on approach	12,329 A: 10,132 P: 1,762 AP: 435	Compared to P, A procedures had: - [b]Lower rates of re-operation (IRR 0.82) - [b]Shorter LOS (−1.0d) - [b]Lower hospital charges (−$2,900)	3
Masaki *et al.* 2007[10]	Retro Cohort	Compare A decompression and fusion with P laminoplasty for cervical myelopathy from OPLL	59 A: 19 P: 40	Compared to P laminoplasty, A decompression and fusion had higher [‡]recovery rate [a](68.4% vs. 52.5%)	3
Oglesby *et al.* 2013[11]	Retro Cohort - Database (NIS)	Determine epidemiological trends among PCD, ACF, and PCF	273,396 ACF: 219,444 PCF: 23,321 PCD: 30,631	Compared to PCF, ACF had: - [†]Lower costs ($14,111 vs. $29,561) - [b]Shorter LOS (2.5 vs. 7.4d) - [†]Lower mortality (13.8% vs. 2.9%)	4
Tanenbaum *et al.* 2017[12]	Retro Cohort - Database (NIS)	Compare ACF with PCF in the treatment of CSM	60,068 A: 45,629 P: 14,439	Compared to PCF, ACF had: - [b]Shorter LOS (−2.4d) - [b]Lower in-hospital charges (−$41,683)	3

(Contd...)

Table 6 : (*Continued*).

Author/Year	Study Design	Objective/Comparison	Sample Size	Key Findings	Level of Evidence
				- [c]Increased risk of dysphagia (OR 2.5) - No difference in hospital mortality (OR 0.91) - [c]More likely to be discharged to self-care (OR 3.0)	

Retro: Retrospective, series: Case series, pre-op: Pre-operative, post-op: Post-operative, LOS: Length of stay, ICU: Intensive care unit, d: Day, ADLs: Activities of daily living, NIS: National Inpatient Sample, CSM: Cervical spondylotic myelopathy, OR: Odds ratio, CI: Confidence interval, OPLL: Ossification of the posterior longitudinal ligament, ACF: Anterior cervical fusion, PCF: Posterior surgical fusion, PCD: Posterior cervical decompression, AP: Anterior and posterior, P: Posterior only, A: Anterior only, mJOA: Modified Japanese Orthopedic Association, ACDF: Anterior cervical discectomy and fusion, MD: Mean difference, IRR: Incidence rate ratio. *RAI, or Risk Assessment Index, is a 14-question validated survey that generates a weighted frailty score using age, gender, living status, medical conditions, cancer status, nutrition, cognition, and ability to perform ADLs. †P-value not provided, [a]$P<0.05$, [b]$P<0.01$, [c]Statistically significant OR/MD and 95% CI, ‡Recovery rate = (postoperative mJOA score - preoperative mJOA score)/(full mJOA score - preoperative mJOA score)

higher hospital payments ($23,638 vs. $18,346), and higher total payments ($33,526 vs. $28,963) versus anterior cervical surgery.[4] The relationship between increased age and the posterior approach is less clear. Masaki *et al*. theorized that older patients were more likely to choose posterior surgery to avoid the lengthier postoperative cervical immobilization period required by anterior cervical fusion.[10]

No significant differences in hospital costs or net revenue for either approach

The present study did not find significant differences in hospital costs or net revenue between anterior versus posterior cervical surgical groups. This may be explained by the smaller sample size or by geographic variation in the costs of spine surgery.[7] For example, Kalakoti *et al*. reported higher average hospital costs associated with anterior cervical discectomy and fusion performed in the Western United States compared to the rest of the country (+$9300; $P < 0.001$).[5]

CONCLUSION

We performed propensity matched scoring and multivariate regression analysis of financial data on 53 patients undergoing anterior versus posterior 1–3 level cervical fusions and found that anterior approaches showed that significantly higher contribution margins compared to posterior surgery after age and length of stay were removed.

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Agarwal N, Goldschmidt E, Taylor T, Roy S, Dunn SC, Bilderback A, *et al*. Impact of frailty on outcomes following spine surgery: A prospective cohort analysis of 668 patients. Neurosurgery 2021;88:552-7.
2. Boakye M, Patil CG, Santarelli J, Ho C, Tian W, Lad SP. Cervical spondylotic myelopathy: Complications and outcomes after spinal fusion. Neurosurgery 2008;62:455-61; discussion 461-2.
3. Cabraja M, Abbushi A, Koeppen D, Kroppenstedt S, Woiciechowsky C. Comparison between anterior and posterior decompression with instrumentation for cervical spondylotic myelopathy: Sagittal alignment and clinical outcome. Neurosurg Focus 2010;28:E15.
4. Cole T, Veeravagu A, Zhang M, Azad TD, Desai A, Ratliff JK. Anterior versus posterior approach for multilevel degenerative cervical disease: A retrospective propensity score-matched study of the marketscan database. Spine (Phila Pa 1976) 2015;40:1033-8.
5. Kalakoti P, Gao Y, Hendrickson NR, Pugely AJ. Preparing for bundled payments in cervical spine surgery: Do we understand the influence of patient, hospital, and procedural factors on the cost and length of stay? Spine (Phila Pa 1976) 2019;44:334-45.
6. Kato S, Ganau M, Fehlings MG. Surgical decision-making in degenerative cervical myelopathy anterior versus posterior approach. J Clin Neurosci 2018;58:7-12.
7. King JT Jr., Abbed KM, Gould GC, Benzel EC, Ghogawala Z. Cervical spine reoperation rates and hospital resource utilization after initial surgery for degenerative cervical spine disease in 12,338 patients in Washington State. Neurosurgery 2009;65:1011-22; discussion 1022-3.
8. Lawrence BD, Jacobs WB, Norvell DC, Hermsmeyer JT, Chapman JR, Brodke DS. Anterior versus posterior approach for treatment of cervical spondylotic myelopathy: A systematic

review. Spine (Phila Pa 1976) 2013;38 22 Suppl 1:S173-82.
9. Luo J, Cao K, Huang S, Li L, Yu T, Cao C, *et al*. Comparison of anterior approach versus posterior approach for the treatment of multilevel cervical spondylotic myelopathy. Eur Spine J 2015;24:1621-30.
10. Masaki Y, Yamazaki M, Okawa A, Aramomi M, Hashimoto M, Koda M, *et al*. An analysis of factors causing poor surgical outcome in patients with cervical myelopathy due to ossification of the posterior longitudinal ligament: Anterior decompression with spinal fusion versus laminoplasty. J Spinal Disord Tech 2007;20:7-13.
11. Oglesby M, Fineberg SJ, Patel AA, Pelton MA, Singh K. Epidemiological trends in cervical spine surgery for degenerative diseases between 2002 and 2009. Spine (Phila Pa 1976) 2013;38:1226-32.
12. Tanenbaum JE, Lubelski D, Rosenbaum BP, Benzel EC, Mroz TE. Propensity-matched analysis of outcomes and hospital charges for anterior versus posterior cervical fusion for cervical spondylotic myelopathy. Clin Spine Surg 2017;30:E1262-8.
13. Zhang L, Chen J, Cao C, Zhang YZ, Shi LF, Zhai JS, *et al*. Anterior versus posterior approach for the therapy of multilevel cervical spondylotic myelopathy: A meta-analysis and systematic review. Arch Orthop Trauma Surg 2019;139:735-42.

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