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Clinical Study

Full-endoscopic spine surgery diminishes surgical site infections – a propensity score-matched analysis

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Abstract

BACKGROUND CONTEXT: Surgical site infections (SSI) are one the most frequent and costly complications following spinal surgery. The SSI rates of different surgical approaches need to be analyzed to successfully minimize SSI occurrence.

PURPOSE: The purpose of this study was to define the rate of SSIs in patients undergoing full-endoscopic spine surgery (FESS) and then to compare this rate against a propensity score-matched cohort from the National Surgical Quality Improvement Program (NSQIP) database.

DESIGN: This is a retrospective multicenter cohort study using a propensity score-matched analysis of prospectively maintained databases.

PATIENT SAMPLE: A total of 1277 noninstrumented FESS cases between 2015 and 2021 were selected for analysis. In the nonendoscopic NSQIP cohort we selected data of 55,882 patients.

OUTCOME MEASURES: The occurrence of any SSI was the primary outcome. We also collected any other perioperative complications, demographic data, comorbidities, operative details, history of smoking, and chronic steroid intake.

METHODS: All FESS cases from a multi-institutional group that underwent surgery from 2015 to 2021 were identified for analysis. A cohort of cases for comparison was identified from the NSQIP database using Current Procedural Terminology of nonendoscopic cervical, thoracic, and lumbar procedures from 2015 to 2019. Trauma cases as well as arthrodesis procedures, surgeries to treat pathologies affecting more than 4 levels or spine tumors that required surgical treatment were excluded. In addition, nonelective cases, and patients with wounds worse than class 1 were also not

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Abbreviations: FESS, full-endoscopic spine surgery; SSI, surgical site infection; MISS, minimally invasive spinal surgery

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included. Patient demographics, comorbidities, and operative details were analyzed for propensity matching.

RESULTS: In the nonpropensity-matched dataset, the endoscopic cohort had a significantly higher incidence of medical comorbidities. The SSI rates for nonendoscopic and endoscopic patients were 1.2% and 0.001%, respectively, in the nonpropensity match cohort (p-value <.011). Propensity score matching yielded 5936 nonendoscopic patients with excellent matching (standard mean difference of 0.007). The SSI rate in the matched population was 1.1%, compared to 0.001% in endoscopic patients with an odds ratio 0.063 (95% confidence interval (CI) 0.009−0.461, p=.006) favoring FESS.

CONCLUSIONS: FESS compares favorably for risk reduction in SSI following spinal decompression surgeries with similar operative characteristics. As a consequence, FESS may be considered the optimal strategy for minimizing SSI morbidity.

Keywords: Full-endoscopic spine surgery; Surgical site infection; Postoperative wound infection; Propensity score matching; Complications; Minimally invasive spinal surgery; Risk factor

Introduction

Postoperative surgical site infections (SSI) constitute a comparably frequent complication following spine surgery that can potentially become a devastating septic condition in case of severe SSIs [1−3]. Infection rates after spine surgery are divergent in current literature, due in part to the operative approach, surgical pathology, and operative segment of the spine. Anterior approaches are typically associated with lower infection rates compared to posterior approaches (2.3% vs. 5.0%, respectively) [4]. Highest incidences can be found after the surgical treatment of metastatic spine pathologies and patients with neuromuscular scoliosis [5,6]. Utilization of instrumentation in spine surgery is also associated with an increased infection risk compared to noninstrumented spine surgery [7,8]. Surgeries for lumbar disc herniations tend to have relatively low rates of infection. For example, the Spine Patient Outcomes Research Trial randomized controlled trial for disc herniation had an incidence of 1.6%, which was shown to be similar to the NSQIP data [9]. In contrast, lumbar decompression surgeries tend to have higher rates of infection, with incidences reported from 3% to 8% in data from prospective randomized controlled trials [10]. Given the heterogeneity of spinal procedures and patient comorbidities estimates for the incidence vary but can be as high as nearly 30% [6,11−14]. A recent meta-analysis showed a pooled incidence for SSI in spine surgery of 3.1% of which 1.7% were deep and 1.4% were superficial SSI [4]. Also, numerous patient-specific factors influence the incidence and outcome of infections. For example, obesity, diabetes, urinary tract infections, blood loss greater than 1,000 mL, intraoperative blood transfusions as well as the duration of surgery have all been identified as a risk factors for SSI [15−17].

Additionally, since SSI is a morbid complication, it is associated with a 5-fold increased risk of readmission and reoperation and a 2-fold increased mortality [3,18]. SSI have shown to negatively impact short-term postoperative recovery of back pain disability and patient satisfaction [19]. SSI also mean a significant economic burden due to increased utilization of health care resources, associated with a median increase length of stay by 2 weeks and an increase in health care costs by up to 300% [20−22].

Management of SSI involves multidisciplinary treatment teams including specialists from infectious disease, internal medicine, and surgery [23]. Given the growing complexity and morbidity of our aging spine surgery population an increasing burden for management of postoperative SSI is carried by hospitalists [24].

Minimally invasive spine surgery (MISS) has been demonstrated to have lower infection rates compared to open techniques [4,25]. Full-endoscopic spine surgery (FESS) constitutes a significant technological advancement of MISS, with comparable patient outcomes compared to open techniques in randomized controlled trials with respect to postoperative pain, speed of recovery as well as improvement in back or neck and extremity pain [26−29]. FESS utilizes a much smaller approach corridor, which minimizes soft tissue damage. Measurements of systemic creatine phosphokinase and c-reactive protein serum levels confirmed minimal muscle injury and systemic inflammatory response following FESS compared to MISS [30]. Moreover, FESS utilizes continuous irrigation which eliminates exposure to aerosolized microbes, continuously removes surgical debride, and might reduce accumulation at the surgical site. While FESS was initially mainly utilized for lumbar disc herniations, the indications have widened significantly [31].

The objective of this prospective multicenter study was to determine the impact of the full-endoscopic surgical technique on the SSI occurrence. We hypothesized that FESS results in less SSI and less wound-related complications when compared to open and MISS techniques.

Methods

Patient selection and data collection

The current study was approved by the institutional review boards of all participating institutions. The participating institutions performed the data collection independently. The investigators prospectively collected data from all FESS

performed between 2015 and 2021, with data maintained on predetermined variables. For this study, we included all patients that underwent noninstrumented full-endoscopic spine surgeries for degenerative spinal pathologies. All postoperative follow-up reports and all blood test results were screened for the possible occurrence of SSI after FESS.

FESS procedures were defined by the utilization of working channel endoscope. In doing so, the surgery was performed using a single tubular retractor. This tube contained the working channel endoscope with the light source, the camera and the irrigation channel. The definition of microsurgery or microsurgical cases in this study was any procedure that required the use of a microscope and did not include the use of endoscopic instruments.

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) was utilized as a comparison data set, which provided sufficient nonendoscopic decompression patients to serve as control and to properly risk-stratify via propensity score matching. Briefly, the ACS-NSQIP is a prospectively maintained, risk-adjusted national surgical outcomes registry that contains data of more than 7.6 million patients from more than 700 participating sites. The data were tracked within a 30-day time window after the index procedure and include pre- and intraoperative variables and postoperative outcomes [32].

The collected data was deidentified to comply with the ACS-NSQIP participant user agreement. Data reliability is ensured with frequent inter-rater audits, with reported disagreement rate of 1.56% [33]. The granularity of the data has been previously validated [34,35]. Using the Current Procedural Terminology (CPT) codes that correspond to nonendoscopic cervical, thoracic, or lumbar decompression procedures, we retrospectively queried the ACS-NSQIP data base from 2015 to 2019 to identify all patients who underwent these procedures. This time period was chosen to most closely resemble the time period for the endoscopic patients. Of these, patients who were operated by nonneurosurgical specialties were excluded. Patients who underwent concurrent arthrodesis procedures or procedures for tumor or trauma were also excluded. The greatest number of operated levels in the endoscopic spine patients was 4; therefore, any nonendoscopic patients with more than 4 levels of operative segments were excluded. Finally, patients who were considered nonelective, emergency or nonclass 1 wound classification were excluded.

Study variables and outcomes

Baseline differences in patient demographics, comorbidities, and operative characteristics were compared, and potential confounders were identified between the endoscopic and the nonendoscopic cohorts. The tracked medical comorbidities included diabetes, history of smoking, dyspnea, history of chronic obstructive pulmonary disease (COPD), history of congestive heart failure (CHF), hypertension, chronic steroid use, and bleeding disorders. These comorbidities were tracked in the ACS-NSQIP, therefore, we prospectively tracked these variables for risk-stratification. Operative details included anatomical level (ie cervical/thoracic/lumbar), number of targeted segments, proportion of inpatients, total operative duration, and American Society of Anesthesiology Classification (ASA).

The primary outcome of this study was any SSI. Relevant to our study, the ACS-NSQIP defines SSI as superficial (skin or subcutaneous tissue), deep (fascial or muscle layers), or as wound disruption (spontaneous opening due to fascial compromise) [36]. When evaluating SSI in endoscopic patients, these definitions were utilized in determining the presence of any SSI.

Statistical analysis plan

IBM SPSS Statistics Version 24 (IBM Corp, Armonk, NY) was used to perform all descriptive and comparative statistics, as well as propensity score matching. Significance was defined at $p<.05$. First, we compared unadjusted variables between the endoscopic and nonendoscopic cohorts. Categorical variables were analyzed by using Pearson χ^2 test or Fisher's exact test when appropriate. Continuous variables were analyzed by using the Student's t test or Mann-Whitney U test in nonnormally distributed variables.

Baseline differences between the cohorts were accounted for by using propensity score matching. The propensity score matching allows for an improved estimate of the treatment effect by balancing observed covariates simultaneously between the cohorts. The details of the theoretical and applied context of propensity score matching are published elsewhere [37]. In brief, we created a nonparsimonious logistic regression model to derive propensity scores for each endoscopic and nonendoscopic patient. Then we used 1:5, greedy, nearest neighbor matching technique without replacement, so that each unique endoscopic patient matches with 5 nonendoscopic patients based on nearest propensity scores. The caliper width used for matching was 0.2. The model adequacy was validated by comparing the standard mean difference of propensity scores between the pre- and postmatched data sets.

The variables used to derive the propensity scores and matching included all demographic, comorbidities, and operative characteristics. Using the matched dataset, we performed separate descriptive and comparative statistics between endoscopic and nonendoscopic cohorts. In order to quantify the SSI risk between the endoscopic and nonendoscopic cohorts, we performed multivariate logistic regression analysis while controlling for potential confounders. The C-index was calculated for the regression model to assess its discriminative ability.

Results

Patient population

A total of 1,278 endoscopic patient data met inclusion criteria. One endoscopic patient was then excluded due to

Table 1
Patient demographics

Patient clinical characteristics						
	Unadjusted			Propensity-matched		
	Nonendoscopic	Endoscopic	p-value	Nonendoscopic	Endoscopic	p-value
N (%)	55,882 (97.8)	1277 (2.2)		5936 (82.5)	1261 (17.5)	
Demographics						
Age (years, mean±SD)	57.9±15.5	60.5±14.9	<.001	60.0±14.4	60.3±14.9	.412
BMI (kg/m^2, mean±SD)	30.5±5.9	30.1±5.7	.017	30.0±5.8	30.1±5.7	.577
Gender			<.001			.234
Male	32,604 (58.3)	642 (50.3)		3108 (52.4)	637 (50.5)	
Female	23,278 (41.7)	635 (49.7)		2828 (47.6)	624 (49.5)	
Race			<.001			<.001
White	44,420 (79.5)	1157 (90.6)		5172 (87.1)	1141 (90.5)	
Black	3838 (6.9)	29 (2.3)		345 (5.8)	29 (2.3)	
Asian	1176 (2.1)	29 (2.3)		79 (1.3)	29 (2.3)	
Other/unspecified	6448 (11.5)	62 (4.9)		340 (5.7)	62 (4.9)	
Medical Comorbidities						
Diabetes	9895 (17.7)	249 (19.5)	.097	1128 (19.0)	242 (19.2)	.877
History of smoking	10,986 (19.7)	565 (44.2)	<.001	2412 (40.6)	549 (43.5)	.057
Dyspnea	1135 (2.0)	16 (1.3)	.050	73 (1.2)	16 (1.3)	.909
History of COPD	2029 (3.6)	57 (4.5)	.117	241 (4.1)	55 (4.4)	.624
CHF	129 (0.2)	23 (1.8)	<.001	68 (1.1)	17 (1.3)	.545
Hypertension	27,807 (49.8)	691 (54.1)	.002	3154 (53.1)	677 (53.7)	.720
Chronic steroid use	2171 (3.9)	142 (11.1)	<.001	591 (10.0)	134 (10.6)	.473
Bleeding disorders	703 (1.3)	32 (2.5)	<.001	137 (2.3)	30 (2.4)	.879

having an arthrodesis procedure, leaving 1277 patients for analysis. Of these patients 57% were full-endoscopic discectomies (AECD, PECD, TETD, TELD, IELD, and EELD), 27% were full-endoscopic laminotomies for bilateral decompression (CE-ULBD, TE-ULBD, and LE-ULBD), 9% were full-endoscopic foraminotomies (PECF, TELF, and ICELF) and 7% were full-endoscopic lumbar lateral recess decompressions (TE-LRD, IE-LRD) [38]. In the nonendoscopic group, a total of 55,882 patients were included for analysis. The unadjusted demographic profile and comorbidities differed significantly between the cohorts (Table 1). The endoscopic group was generally older and had a greater proportion of females. There was also a significantly higher proportion of patients who had history of smoking, CHF, hypertension, chronic steroid use, and bleeding disorders in this group. The operative characteristics were also significantly different between the cohorts (Table 2). A greater proportion of endoscopic patients had thoracic decompression and surgery at a single spinal level. In contrast, more nonendoscopic patients required inpatient stay (33.2 vs. 26.2%, p<.001). The total mean operative duration was similar. ASA classification was also significantly different between the cohorts.

Propensity score matching yielded well-matched cohorts of 5936 nonendoscopic and 1261 endoscopic patients (Table 1). The standard mean difference of propensity scores prior to and after matching were 0.524 and 0.007, respectively. After matching, the demographic and comorbidities were no longer statistically different between the cohorts with the exception of race. Similarly, many of the differences in operative characteristics were also abolished except for multicategorical variables such as anatomical level and ASA classification.

Surgical site infection

In the unadjusted population, the SSI rates for nonendoscopic and endoscopic patients were 1.2% and 0.001%, respectively (Table 3). The SSI rates in the matched populations were similar, with nonendoscopic patients having 1.1% and endoscopic patients 0.001% SSI rate. In the endoscopic cohort only one superficial SSI was observed. In our multivariate analysis of matched population, which controlled for potential confounders, we found that endoscopic patients had statistically significant reduction of SSI compared to nonendoscopic patients (odds ratio [OR] 0.063, 95% CI 0.009–0.461, p=.006). Of the included potential confounders, only lumbar decompression (OR, 0.424, p=.012) and 2-level surgery (OR, 1.909, p=.024) were significantly associated with SSI. The C-index for the regression model was 0.797, which demonstrated strong discriminative capacity. None of the surgeons in the FESS group routinely utilized irrigation fluid containing antibiotics during the FESS procedures.

Discussion

In comparison of the 2 prospectively maintained cohorts of patients that underwent spine surgery, the use of FESS was associated with a dramatically diminished risk of SSI as compared to traditional surgical technique. With reducing confounding by comparison of propensity matched

Table 2
Patient operative characteristics

	Unadjusted			Propensity-Matched		
	Nonendoscopic	Endoscopic	p-value	Nonendoscopic	Endoscopic	p-value
N (%)	55,882 (97.8)	1277 (2.2)		5936 (82.5)	1261 (17.5)	
Clinical Details						
Anatomical level			<.001			<.001
Cervical	3839 (6.9)	91 (7.1)		466 (7.9)	90 (7.1)	
Thoracic	171 (0.3)	19 (1.5)		25 (0.4)	19 (1.5)	
Lumbar	51,872 (92.8)	1167 (91.4)		5445 (91.7)	1152 (91.4)	
Number of segments			<.001			.088
1	38,695 (69.2)	1063 (83.2)		4811 (81.0)	1049 (83.2)	
2	13,958 (25.0)	201 (15.7)		1009 (17.0)	199 (15.8)	
3	2365 (4.2)	12 (0.9)		103 (1.7)	12 (1.0)	
4	864 (1.5)	1 (0.1)		13 (0.2)	1 (0.1)	
Inpatient	18,547 (33.2)	335 (26.2)	<.001	1624 (27.4)	332 (26.3)	.455
Total operative time (minutes)	96±45	99±77	.098	99±48	99±77	.746
ASA Class			<.001			<.001
Class 1	3391 (6.1)	219 (17.1)		368 (6.2)	212 (16.8)	
Class 2	28,398 (50.8)	482 (37.7)		3404 (57.3)	477 (37.8)	
Class 3	23,146 (41.4)	569 (44.6)		2093 (35.3)	565 (44.8)	
Class 4	947 (1.7)	7 (0.5)		71 (1.2)	7 (0.6)	

Table 3
Propensity-score analysis and multivariate analysis

Patient operative characteristics						
	Unadjusted		p-value	Propensity-matched		
	Nonendoscopic	Endoscopic		Nonendoscopic	Endoscopic	p-value
N (%)	55,882 (97.8)	1277 (2.2)		5936 (82.5)	1261 (17.5)	
Surgical site infection	666 (1.2)	1 (0.001)	**<.011**	67 (1.1)	1 (0.001)	**<.001**
Multivariate analysis						
	Surgical site infection		p-value			
	Odds ratio	95% CI				
Endoscopic	**0.063**	**0.009−0.461**	**.006**			
Male	0.679	0.415−1.110	.123			
Race						
Black	1.001	0.389−2.579	.998			
Asian	1.446	0.191−10.963	.721			
Other	1.479	0.618−3.537	.379			
Surgical Segment						
Thoracic	0	0	.998			
Lumbar	**0.424**	**0.218−0.827**	**.012**			
Number of Segments						
2	**1.909**	**1.090−3.344**	**.024**			
3	1.952	0.451−8.452	.371			
4	0	0	.999			
Inpatient	1.493	0.874−2.553	.143			
Age	0.983	0.962−1.004	.105			
Diabetes	1.785	0.998−3.194	.051			
Smoking	1.635	0.984−2.719	.058			
Dyspnea	0	0	.997			
History of COPD	0.585	0.137−2.496	.469			
CHF	1.227	0.160−9.417	.844			
HTN	0.758	0.425−1.352	.348			
Chronic Steroid	0.756	0.299−1.913	.555			
Bleeding disorders	0	0	.995			
ASA Classification	1.182	1.010−1.383	.037			
2	1.036	0.302−-3.551	.955			
3	1.835	0.497−6.770	.362			
4	0	0	.997			
Total operative time	1.004	1.000−1.009	.074			

Bolded values represent statistically significant results.

cohort, we demonstrate a 16-fold risk reduction of SSI occurrence in the group undergoing FESS.

MISS has been demonstrated to be associated with a low rate of SSI [39]. This study of 1338 tubular spine surgeries detected a rate of 0.1% infections in non-instrumented and 0.75% in instrumented spine surgeries in a single institution. A recent meta-analysis reported SSI rates of 1.5% after MISS vs. 3.8% after open spine surgery [4]. Our results demonstrate an even further reduction of risk to 0.001%, compared to 1.1% after non-FESS procedures. Importantly, as described, the surgeons in the FESS cohort did not utilize antibiotic irrigation. Anyhow, continously irrigating the surgical field with saline is a standardized part of FESS to maintain clear vision and it might effectively lead to the distinct reduction of SSI by preventing significant bacterial colonization.

Several factors likely contribute to the low infection rate in full-endoscopic surgeries. First, the volume of tissue disruption is limited when performing FESS. Endoscopes range from 7 to 10 mm in diameter; whereas MISS tubes range from 16 to 22 mm in diameter and open surgeries are even greater. Biochemical evidence is consistent with minimal tissue trauma from FESS [30]. Minimizing the tissue trauma by reducing the extent of the surgical cavity is known to alleviate the risk for SSI in other surgical fields [40]. Second, continuous irrigation of the surgical field eliminates aerosolized microbes from entering the wound, with sterile fluid providing outward flow as mentioned before. The airborne bacteria of the surgeon and staff as well as skin flora of the patient are likely to have reduced exposure to the wound. Thirdly, FESS is associated with minimal blood loss, which might also contribute – as elevated blood loss has been associated with infection risk - and/or systemic stress - and clotted blood is a possible breeding ground for bacteria [41].

We acknowledge limitations of the current study: The CPT code used to query nonendoscopic data from the ACS-NSQIP which may contain MISS decompression procedures or even endoscopic procedures coded as open decompression. Although we reduced baseline differences by employing propensity score matching and multivariate analyses, we cannot eliminate differences that arise from unknown variables. The minimum follow-up time of patients in the FESS cohort was 6 months allowing for assessment of risk reduction of both acute and delayed SSI. The follow-up time of patients in the ACS-NSQIP is only 30 days. While most SSI occur within this time frame, the data collected in the ACS-NSQIP would not detect SSI occurring after this time frame. Consequently, the estimated risk for SSI in the FESS group is presumably even lower than detected in our study. In addition, the NSQIP database was not as detailed as our FESS database in terms of the exact surgical technique which can cause granularity deficiencies. Since the focus of our study was on SSI occurrence, our data does also not support conclusions on the influence of FESS on patient-related outcome measures and any superiority of FESS or MISS regarding that topic. Since the authors are part of the endoscopic research community, a certain extent of study bias must also be listed as one of this study's limitations.

Conclusions

In both propensity-matched and non-matched comparisons, FESS dramatically reduced the risk of SSI with approximately 16-fold risk reduction. The rate of SSI in FESS is the lowest in published literature. The infection rate of 0.001% was derived from a large, multi-institutional group, which reflects the general practice of FESS instead

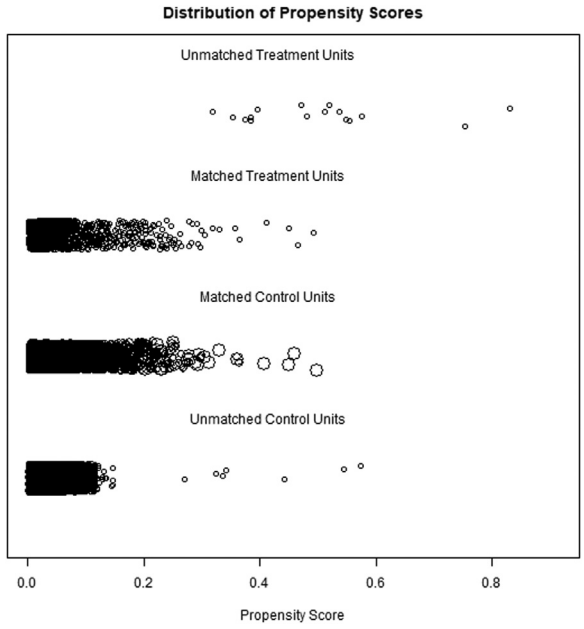

Fig. 1. Distribution of propensity scores.

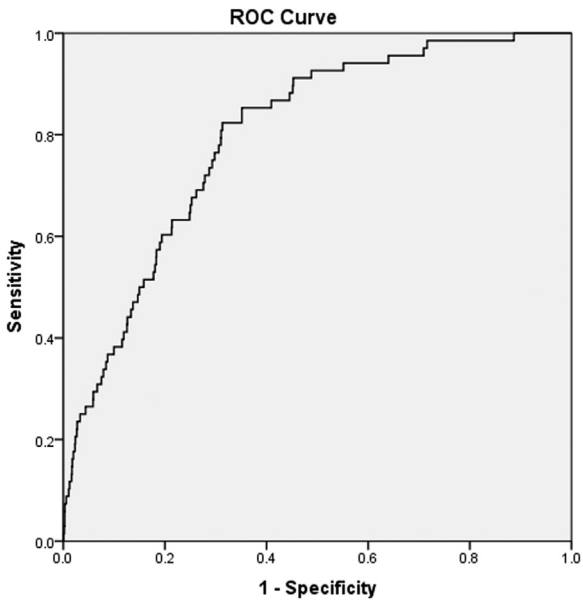

Fig. 2. ROC curve.

of single institutions or surgeon case-series. Potential cost savings may be associated with FESS, which will require further research as well as the analysis to what extent the low SSI rates affect the patients' clinical outcome (Figs. 1 and 2).

Declarations of competing interests

One or more of the authors declare financial or professional relationships on ICMJE-TSJ disclosure forms.

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