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Clinical study

Impact of medical student involvement on outcomes following spine surgery: A single center analysis of 6485 patients

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ABSTRACT

Medical student (MS) observation and assistance in the operating room (OR) is a critical component of medical education. Though participation in the operating room has many benefits to the medical student, the potential cost of these experiences to the patients must be taken into account. Other studies have shown differences in outcomes with resident involvement, but the effect of medical students in the OR has been poorly understood. The objective of this study was to understand how medical students and residents impacted surgical outcomes in posterior spinal fusions, anterior cervical discectomy and fusions (ACDFs), and lumbar discectomies. We conducted a retrospective study of patients undergoing posterior spinal fusions, ACDFs, and lumbar discectomies over 15 years. There were 6485 patients met the inclusion criteria of either undergoing a posterior fusion, ACDF or lumbar discectomy (1250 posterior fusion, 1381 ACDF, 3854 lumbar discectomies). Overall, little difference was observed when a medical student was present for surgical outcomes including length of stay, infection, and readmission. For ACDFs, having a medical student present had a significantly longer procedure durations (OR = 1.612, p = 0.001) than cases without. Besides slightly longer operative time (in posterior fusions), there were no major differences in outcomes when a medical student was present in the OR.

1. Introduction

Medical student (MS) observation and assistance in the operating room (OR) is a critical component of medical education [1]. Through these experiences, medical students gain an intricate understanding of the dynamics of surgery and the nature of the procedure [2]. In addition, observation during the clerkship years is seminal when deciding which medical specialty to pursue [3]. In the OR, medical students will assist with tasks such as retracting and suctioning during the more critical portions of the procedure and assist the resident with opening and closing. In addition, students also have the opportunity as a member of the service to follow the patient postoperatively and write progress notes and daily plans to help prepare for medical residency [4].

Though participation in the operating room has many benefits to the medical student, the potential cost of these experiences to the patients must be taken into account. Human error within healthcare has been well studied over the past decade and the cost to the overall United States health care system can be substantial [5,6]. Certain variables that are more prone to human error, such as surgical site infections (SSIs), can be costly; SSIs are a preventable complication that can have drastic effects on a patient's functional outcomes and leads to costs around $25,546 [7,8]. Another modifiable factor is operative length which can add additional cost to a procedure ($35–$95 per hour), and can lead to increased time under general anesthesia [9,10]. Finally, patient length of stay and readmissions are also factors that have a significant burden on the healthcare system and are avoidable complications. Every additional day in the hospital ($1644–$3581 per day) and avoidable readmissions (ranging from $10,000 to $58,000) can have a devastating cost on a health system [11,12].

There have been several studies investigating whether residents in the OR have any impact on the above variables. Multiple cohorts across multiple surgical specialties (breast, general, and plastics) have shown no notable difference in outcomes such as patient morbidity and mortality [13–15]. There were, however, small differences observed with residents in cases regarding soft tissue infections, but the difference between the groups was small (3% versus 2.2%) [16]. A few studies have been published investigating

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medical students in the OR, but no major significant findings have been established.

The objective of this study was to understand how medical students and residents impacted surgical outcomes in posterior spinal fusions, anterior cervical discectomy and fusions (ACDFs), and discectomies.

2. Methods

2.1. Data source

All patients who underwent spine surgery at our institution between January 1st, 2006 and December 31st, 2015 were identified using the Northwestern University Electronic Data Warehouse (EDW). The EDW is a clinical data repository jointly funded by Northwestern Memorial Hospital (NMH), Northwestern Medical Faculty Foundation (NMFF), and Northwestern University Feinberg School of Medicine. The three most prevalent procedures were identified: posterior spinal interbody fusion, anterior cervical discectomy and fusion, and posterior lumbar discectomies. For each surgery included in the study, we collected data regarding the patient, procedure, postoperative management, and recovery. The study was approved by the Institutional Review Board (IRB).

2.2. Patient and outcomes data

There were 6485 patients met the inclusion criteria of either undergoing a posterior fusion, ACDF or lumbar discectomy (1250 posterior fusion, 1381 ACDF, 3854 lumbar discectomies). We investigated the following for all 6485 patients: BMI, gender, race, length of stay, infection, prior myocardial ischemia (MI), acute heart failure, prior pulmonary embolism, prior pneumonia, renal disease, postoperative venous thromboembolism, type of operation, revision, complication, and Charlson Comorbidity Index, as identified by the ninth edition of International Classification of Disease (ICD-9) codes. Additionally, we collected included total OR duration, length of stay, 30-day hospital readmission and wound infection. For all fusion procedures, we also noted the number of levels fused and the location of the fusion. All case notes were further reviewed for documentation of medical student presence.

2.3. Statistical methods

Microsoft Excel 2011 (2011, Microsoft, Redmond, WA, USA) was used for data management, and STATA 12.0 (2011, StataCorp, College Station, Texas, USA) and Prism 6.0b (2012, GraphPad Software, Inc., La Jolla, CA, USA) were utilized to conduct statistical analyses. Parametric data was given as mean ± standard deviation and compared by the Student's *t*-Test, and non-parametric data was compared using Mann-Whitney *U* test, Kruskal-Wallis test or Chi-square tests, as appropriate. Spearman's rank correlation test was used to establish correlation with a rho value of |0.3| to define correlation. Regression analysis was performed using both univariate modeling methods as well as reasonable multivariate controlled models. P-values of < 0.05 were considered statistically significant.

3. Results

Overall, 6485 patients were included in this study (1250 posterior fusions, 1381 ACDFs, 3854 discectomies) (see Tables 1–5).

3.1. Posterior fusions

1250 cases of posterior spinal interbody fusion were included. There was no significant difference in patient age (58.09 vs 57.77 years, $p > 0.05$) regardless of medical student presence or absence. Univariate analysis revealed no significant difference in infection (OR = 1.005, $p = 0.990$), procedure duration (OR = 0.858, $p = 0.307$), length of stay (OR = 0.822, $p = 0.208$), or readmission (OR = 0.810, $p = 0.676$). Multivariate analysis indicated that the presence of a medical student was not significant for infection (OR = 0.992, $p = 0.320$), readmission (OR = 0.810, $p = 0.683$), procedure duration (coefficient = −3.94, $p = 0.640$), or length of stay (coefficient = −0.204, $p = 0.467$). Charlson Comorbidity Index (OR = 1.171, $p < 0.001$) and number of levels fused (OR = 1.223, $p < 0.001$) were found to be significant risk factors for readmission. An increased number of levels fused (coefficient = 18.9, $p < 0.001$) was a significant factor for longer procedure duration. Finally, procedure duration (coefficient = 0.0077, $p < 0.001$), Charlson Comorbidity Index (coefficient = 0.202, $p < 0.001$) and number of levels fused (coefficient = 0.559, $p < 0.001$) were found to significantly contribute to overall postoperative length of stay.

3.2. Anterior cervical discectomy and fusion

1381 cases of ACDF were included. There was no significant difference in patient age (51.30 vs 51.81 years, $p > 0.05$) regardless of medical student presence or absence. Univariate analysis revealed no significant difference in infection (OR = 0.945, $p = 0.945$), length of stay (OR = 1.203, $p = 0.257$), or readmission (OR = 1.423, $p = 0.575$). However, cases in which a medical student was present had a significantly longer procedure duration (OR = 1.612,

Table 1
Patient operative/clinical characteristics.

		Medical Students	No Medical Students	P-Value
Posterior Fusions (N = 1250)	Age (years, mean ± SD)	58.09 ± 14.52	57.77 ± 15.18	0.7342
	Length of Stay (days)	5.59 ± 4.96	5.48 ± 4.39	0.7227
	Procedure Duration (min)	276.32 ± 140.12	275.09 ± 145.6	0.8921
	Charlson Comorbidity Index	2.25 ± 3.08	2.38 ± 3.05	0.5076
	Number of Levels Fused	2.73 ± 2.36	2.88 ± 2.43	0.3029
ACDFs (N = 1381)	Age (years, mean ± SD)	51.30 ± 12.01	51.81 ± 12.25	0.4879
	Length of Stay (days)	2.16 ± 3.56	2.24 ± 3.05	0.7352
	Procedure Duration (min)	151.80 ± 89.08	169.97 ± 101.52	**0.0014***
	Charlson Comorbidity Index	1.36 ± 2.12	1.65 ± 2.42	**0.0318***
	Number of Levels Fused	1.69 ± 0.81	1.74 ± 0.93	0.3124
Discectomy (N = 3854)	Age (years, mean ± SD)	44.07 ± 13.66	44.07 ± 13.42	0.9969
	Length of Stay (days)	1.20 ± 0.97	1.18 ± 0.79	0.7289
	Procedure Duration (min)	84.42 ± 39.60	87.14 ± 73.28	0.1852
	Charlson Comorbidity Index	0.90 ± 1.86	1.02 ± 2.14	0.1531
	Number of Levels Fused	–	–	–

SD indicates standard deviation.
* Denotes significant value, $p < 0.05$.

Table 2
Univariate regression of outcomes with respect to presence of medical students.

		Binary Outcomes			Continuous Outcomes	
		OR	P-value		Coefficient	P-value
Posterior Fusions (N = 1250)	Procedure Duration in the top 25%	0.858	0.307	Procedure Duration	0.2922470	0.892
	Length of Stay in Top 25%	0.822	0.208	Length of Stay	0.8954066	0.723
	Infection	1.005	0.990			
	Readmission	0.810	0.676			
ACDFs (N = 1381)	Procedure Duration in the top 25%	1.612	**0.001***	Procedure Duration	7.78E + 07	**0.001***
	Length of Stay in Top 25%	1.203	0.257	Length of Stay	1.076918	0.735
	Infection	0.945	0.945			
	Readmission	1.423	0.575			
Discectomy (N = 3854)	Procedure Duration in the top 25%	1.108	0.311	Procedure Duration	1.5165030	0.185
	Length of Stay in Top 25%	0.991	0.958	Length of Stay	0.9848815	0.729
	Infection	0.779	0.500			
	Readmission	0.630	0.147			

OR indicates odds-ratio.
* Denotes significant value, p < 0.05.

Table 3
Multivariate regression of outcomes for posterior spinal fusions (N = 1250).

	Binary Outcomes			Continuous Outcomes	
	OR	P-value		Coefficient	P-value
Infection			**Procedure Duration**		
Presence of a Medical Student	0.9921885	0.9851296	Presence of a Medical Student	0.0193683	0.6473576
Age	1.0269600	0.0768873	Age	1.212445	0.4730703
Charlson Comorbidity Index	1.1015210	0.0444015	Charlson Comorbidity Index	0.2389821	0.2685925
Number of Levels Fused	0.9633944	0.6726379	Number of Levels Fused	1.55E+08	6.01E−30
Procedure Duration	1.0010600	0.3200085	Procedure Duration	–	–
Readmission			**Length of Stay**		
Presence of a Medical Student	0.8106284	0.6863707	Presence of a Medical Student	0.8154865	0.4671393
Age	1.016593	0.3436655	Age	1.003923	0.6533264
Charlson Comorbidity Index	1.171396	0.0013122	Charlson Comorbidity Index	1.224317	1.84E−06
Number of Levels Fused	1.223469	0.0006504	Number of Levels Fused	1.750135	7.88E−22
Procedure Duration	0.996505	0.0682970	Procedure Duration	1.007742	1.56E−16

OR indicates odds-ratio.

Table 4
Multivariate regression of outcomes for ACDFs (N = 1381).

	Binary Outcomes			Continuous Outcomes	
	OR	P-value		Coefficient	P-value
Infection			**Procedure Duration**		
Presence of a Medical Student	0.8954391	0.8934388	Presence of a Medical Student	1.3401450	0.0028994
Age	1.0562280	0.0711510	Age	0.6159964	0.0072535
Charlson Comorbidity Index	1.1255950	0.3138310	Charlson Comorbidity Index	6.0953980	0.0000286
Number of Levels Fused	1.4742260	0.3668418	Number of Levels Fused	7.86E + 25	3.20E−104
Procedure Duration	0.9986101	0.7778706	Procedure Duration	–	–
Readmission			**Length of Stay**		
Presence of a Medical Student	1.3638230	0.6157219	Presence of a Medical Student	0.8782893	0.5218030
Age	1.0272240	0.2626335	Age	1.0145610	0.0604571
Charlson Comorbidity Index	1.0411100	0.7328359	Charlson Comorbidity Index	1.1957820	0.0000230
Number of Levels Fused	0.6908062	0.3860804	Number of Levels Fused	2.2536260	2.43E−10
Procedure Duration	1.0015230	0.5765281	Procedure Duration	1.0065010	1.62E−08

OR indicates odds-ratio.

p = 0.001) than cases without. Multivariate analysis revealed that the presence of a medical student did not significantly influence infection rates (OR = 0.895, p = 0.893), readmission (OR = 1.363, p = 0.615) or length of stay (coefficient = −0.1297, p = 0.521). However, the presence of a medical student significantly lengthened the duration of surgery (coefficient = 14.108, p = 0.002). Increased age (coefficient = −0.484, p = 0.007), Charlson Comorbidity Index (coefficient = 4.11, p < 0.001), and an increased number of levels fused (coefficient = 59.6, p < 0.001) were found to significantly increase the procedure duration as well. Finally, procedure duration (coefficient = 0.006, p < 0.001), Charlson Comorbidity Index (coefficient = 0.202, p < 0.001) and number of levels fused (coeffi-

Table 5
Multivariate regression of outcomes for discectomy (N = 3854).

	Binary Outcomes			Continuous Outcomes	
	OR	P-value		Coefficient	P-value
Infection			**Procedure Duration**		
Presence of a Medical Student	0.7296195	0.4146571	Presence of a Medical Student	12.15041	0.2190251
Age	0.9949529	0.6063858	Age	1.405232	5.79E−09
Charlson Comorbidity Index	1.182944	0.0001979	Charlson Comorbidity Index	6.397333	8.71E−06
Procedure Duration	1.000386	0.8703294	Procedure Duration	–	–
Readmission			**Length of Stay**		
Presence of a Medical Student	0.6028888	0.1372675	Presence of a Medical Student	0.9636148	0.3782554
Age	1.0023080	0.7768339	Age	1.0064880	2.15E−07
Charlson Comorbidity Index	1.1739700	0.0000390	Charlson Comorbidity Index	1.0468750	1.20E−07
Procedure Duration	0.9951156	0.1034404	Procedure Duration	1.0044540	2.15E−41

OR indicates odds-ratio.

cient = 0.178, p < 0.001) and number of levels fused (coefficient = 0.8125, p < 0.001) were found to significantly contribute to length of stay.

3.3. Discectomy

3854 cases of discectomy were included. There was no significant difference in patient age (44.07 vs 44.07 **p > 0.05**) regardless of medical student presence or absence. Univariate analysis revealed no significant difference in infection rates (OR = 0.779, p = 0.500), procedure duration (OR = 1.108, p = 0.311), length of stay (OR = 0.991, p = 0.958), or readmission (OR = 0.630, p = 0.147) among cases with medical students compared to without. Multivariate analysis indicated the presence of a medical student was not significant for infection (OR = 0.7296, p = 0.414), readmission (OR = 0.602, p = 0.137), procedure duration (coefficient = 2.94, p = 0.219), or length of stay (coefficient = −0.037, p = 0.378). Increased Charlson Comorbidity Index (OR = 1.183, p < 0.001) was found to be a significant contributor to greater infection rates. For readmission, Charlson Comorbidity Index (OR = 1.171, p < 0.001) was found to be significant risk factor. For procedure duration, both age (coefficient = 0.340, p < 0.001) and Charlson Comorbidity Index (coefficient = 1.855, p < 0.001) were found to be significant. Finally, procedure duration (coefficient = 0.0044, p < 0.001), Charlson Comorbidity Index (coefficient = 0.0458, p < 0.001) and age (coefficient = 0.0065, p < 0.001) were found to significantly contribute to length of stay.

4. Discussion

Our findings suggest that medical students have a minimal impact on the outcomes for common neurological surgery procedures. This is an encouraging finding, as medical education – especially in the operating room – is a crucial component for training future surgeons [17]. These findings are consistent with what has been found in several other fields. In our investigation we focused on factors that are known contributors to increased patient mortality and morbidity along with increased associated costs to the healthcare system.

For procedure duration, univariate analysis revealed a significant difference in duration of procedure with and without medical students for ACDFs, though this was not observed via multivariate analysis. Not surprisingly, an increased number of levels involved in the surgery was consistently a significant factor for increased procedure duration for all three groups of surgeries observed. Age and Charlson Comorbidity Index were also significant factors for increased ACDF and discectomy operation time. Notably, the presence of medical students was not found to significantly contribute to infection rates. However, we did find Charlson Comorbidity Index to significantly influence infection rates in discectomy procedures.

For length of stay medical students did not contribute additional time; however Charlson Comorbidity Index, procedure duration, number of levels fused were found to be significant contributors on multivariate analysis for all included procedures. Finally, for readmission, medical students were not a significant contributor, but on multivariate analysis, the Charlson Comorbidity Index contributed significantly for both posterior fusions and discectomy and number of levels fused was only significant for posterior fusions.

Other studies have investigated these factors in the setting of trainees in the operating room. Similar to what we found with ACDF surgeries (an increase of 14 min per case), medical students have been shown to increase operative times in other surgical settings. Hagopian et al. found that medical students added an additional 14 min in a multicenter review of 2841 inpatient general surgery cases [4]. In a retrospective review of 700 laparoscopic general surgery cases an increase of 28 min was observed with a medical student present in the case [1]. Interestingly, in a retrospective study of 70 bilateral mammoplasties, Liao et al. found that medical students increased the incision to skin closure duration by roughly 15 min, but did not find a significant difference in the actual procedure time (time necessary for the OR) [18]. Even with more experiences trainees such as residents, where a review of 10,356 reconstructive plastic surgery cases revealed a 30 min increase in case time [15]. In a recently published study reviewing 5655 lumbar fusions, Yamaguchi et al. found that residents increased the operative duration by 45 min [19]. Duration of surgery is a crucial metric as longer procedures can often result in higher cost, impose a negative impact on staff scheduling and decrease the efficiency of the operating room [18]. Optimizing OR times is crucial as institutions have reported costs of OR times ranging from $62 to $95 dollars per hour [20]. Furthermore, with the cost of surgeons waiting for their scheduled procedures can also compound and has been shown to contribute thousands of dollars to the bottom line of a procedure [21].

Trainees have been previously reported to lengthen OR time [22]. One speculation includes the primary surgeon taking extra time to demonstrate certain procedures to medical students. The other possibility is that medical students often opt to attend cases where the least number of residents are present, with the hope that they would assume more active roles in assisting the surgeon rather than observing or picking up surgical materials. This could inadvertently result in the primary surgeon gaining a less experienced assistant compared to a resident and thus resulting in longer surgical duration in the OR.

SSIs remain a crucial focus, as they are a preventable, costly burden on any health system [23]. Raval et al. studied the effects of the presence of residents on different surgical outcomes across 234 hospitals and found an 21.2% increase in infection rates with a surgical resident present. These findings were confounded due to the propensity for residents to be assisting in more complex cases with more medically complicated patients [24]. Similar to our findings, several studies investigated infection rates within the field of general surgery and found that residents had no impact on infection rates [1,4]. It is well understood that postoperative infections can lead to significant increases in the cost of care and can result in decreased outcomes, especially in spine surgery where adequate fusion plays an essential role in the patients post-operative functionality. Numerous studies have highlighted that surgical site infections in the setting of spine fusions can lead to detrimental outcomes such as reoperation, infection recurrence, increased length of stay, and increased risk of 180-day readmission [25–27]. Other factors have also been implicated in SSIs within the field including obesity and prolonged operating time [27–29]. This resonates with previous studies done in US where the cost of healthcare associated infections amounted up to as high as $40 billion annually [8].

Medical student presence in the operating room did not influence OR time. Interestingly, the duration of the procedure had a statistically significant, but marginal increase in duration of stay. The largest coefficient seen was 0.0077 which indicates that every additional minute of surgery has a minute impact on the patients stay and would not affect cost. This is also related to the number of levels included which has a much higher correlation to the duration of stay. This is to be expected as an increased number of levels involved equates to a more complex case, which would lead to a longer recovery time [30]. However, one previous study demonstrated that resident involvement led to increased hospitalization duration [31].

Finally, there was a relationship between the Charlson Comorbidity Index and the duration of stay and readmission. Our results showed that for our all three observed procedures (Posterior fusions, ACDFs, and discectomy), procedure duration, Charlson Comorbidity Index, and number of levels fused all contribute significantly towards increased length of hospitalization for patients. This is once again to be expected as patients with more comorbidities or complex cases typically have more complicated recoveries and are more likely to have prolonged hospital stays along with higher rates of readmission [32,33]. Previous studies on patients with ischemic and hemorrhagic stroke show that higher CCI scores led to increased length of hospitalization for patients [34].

Similarly, a 2017 study on the relationship between CCI Scores and length of hospitalization showed that higher CCI scores led to increased length of stay in hip/pelvis orthopaedic trauma patients [32]. While our study shows that the presence of medical students had no significant effect on the patients' length of stay, Jordan et al., showed that the presence of residents had significant effect by increasing the length of stay by 1 day in patients who underwent plastic surgery [15]. However, it should be noted that residents were involved in cases where patients tend to be smokers and obese compared to cases where residents were not present. Though no previous studies have investigated the association between medical students and patients' readmission rates or length of stay, Southern et al. have found that teaching hospitals tend to have patients who had lower length of stay than non-teaching hospitals, which could imply the difference in quality of care that could arise from medical students and residents. Teaching hospitals also showed a lower trend of readmission rate compared to non-teaching hospitals, but it was not significant [35].

5. Limitations

The main limitation of this study is its retrospective in nature, which limits what factors can be included in the study. Hence, the data is dependent upon proper documentation of medical records. Another limitation is that surgical experiences of the attending physicians were not recorded, mentioned, or controlled for, which could interfere with our data regarding the extent medical student presence exhibited its true effects on dependent variables. Additionally, patients were operated on by multiple spinal surgeons at a single institution, which may have resulted in heterogeneity via variability in surgical techniques. Moreover, while we were able to record MS presence in the OR, the degree of their participation in the OR was not measured qualitatively. Secondly, data regarding cases with or without the presence of medical students was retrieved from a single institution. While one may generalize that medical student involvement in the OR is similar across the world, the environments of the OR across multiple hospitals may be different in terms of settings and hygiene. Moreover, inhabitants of the community may be different in terms of health conditions and vulnerability to certain diseases. While this study highlights that the presence of medical students resulted in increased operative time – and therefore, increased financial costs, patients often view medical students' involvement in their care as a positive aspect [36].

6. Conclusion

We found no major differences in common neurological surgery procedures (posterior fusion, ACDF, lumbar discectomy) when a medical student was present in the OR. This was the first study to evaluate these parameters within this arena. This is an important finding as it confirms that medical students can benefit from educational OR experiences while maintaining a safe environment for the patient.

Previous presentations

This work has not been previously presented elsewhere.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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