Effect of Resident Involvement on Morbidity and Mortality Following Thoracic Endovascular Aortic Repair

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OBJECTIVE: To evaluate the effect of resident involvement in thoracic endovascular aortic repair (TEVAR).

SUMMARY OF BACKGROUND DATA: Although the influence of resident intraoperative involvement in several types of surgical procedures has been reported, the effect of resident participation in TEVAR is unknown. We evaluated patient outcomes in resident-involved TEVAR procedures.

METHODS: The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was analyzed for TEVAR performed from 2010 to 2012. Current procedural terminology codes were used to identify adult patients (≥18 y) who underwent TEVAR. Patients were grouped into those with and without resident involvement. Descriptive and binomial logistic statistics were used to determine the effect of resident involvement on post-TEVAR outcomes. p values < 0.05 were considered statistically significant.

RESULTS: A total of 676 patients met inclusion criteria for this study. Of these, 517 (76.5%) had residents involved. Overall mortality was 9.8%, with no significant difference between the 2 groups (p = 0.88). Resident involvement was not a significant predictor of any post-TEVAR complication. Postoperative pneumonia (3.5% vs 6.9%, p = 0.06), prolonged mechanical ventilation (11.8% vs 11.9%, p = 0.96), stroke (2.7% vs 5.7%, p = 0.07), urinary tract infection (3.3% vs 4.4%, p = 0.50), progressive renal insufficiency (1.2% vs 2.5%, p = 0.22), acute renal failure (4.1% vs 5.0%, p = 0.60), cardiac arrest (2.9% vs 5.0%, p = 0.20), myocardial infarction (1.7% vs 1.9%, p = 0.91), deep venous thrombosis (1.7% vs 1.3%, p = 0.67), red blood cells transfusions (29.2% vs 36.5%, p = 0.08), sepsis (2.9% vs 4.4%, p = 0.35), septic shock (1.9% vs 3.8%, p = 0.18), and unplanned reintubation (8.7% vs 9.4%, p = 0.78) were not significantly affected. Additionally, resident involvement did not significantly affect operative time (176.1 ± 122.8 min vs 180.3 ± 119.1 min, p = 0.71) and anesthesia time (282.1 ± 146.6 min vs 278.3 ± 140.5 min, p = 0.78).

CONCLUSIONS: The participation of residents in TEVAR did not significantly affect all 30-day patient outcomes. Resident involvement in TEVAR is safe and should be encouraged.

MINI ABSTRACT: This study evaluated the effect of resident participation on postoperative outcomes of thoracic endovascular aortic repair (TEVAR) using the American College of Surgeons National Surgical Quality Improvement (ACS-NSQIP) database. Results showed that resident involvement in TEVAR does not negatively affect patient outcomes. (J Surg Ed 75:1575−1582. © 2018 Published by Elsevier Inc. on behalf of Association of Program Directors in Surgery.)

KEYWORDS: thoracic aortic dissection, thoracic aortic aneurysm, endovascular, resident, outcome

COMPETENCIES: Patient Care, Systems-Based Practice, Medical Knowledge, Practice-Based Learning and Improvement

INTRODUCTION

Thoracic aortic aneurysm (TAA) and thoracic aortic dissection (TAD) though rare are potentially catastrophic and may require immediate treatment.[1] Thoracic endovascular aortic repair (TEVAR) is an emerging technology for the treatment of thoracic aortic pathologies (TAA/TAD) and remains an appealing alternative to open surgery.[2-4] Since its introduction in 1994,[3] there has been an uptrend in the number of TEVAR procedures performed in the United States. And with its

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minimally invasive approach that leads to shorter hospital stay, smaller surgical incisions, and decreased associated postoperative morbidity and mortality, TEVAR is not only attractive to surgeons but also to patients. Scali et al.[4] report that from 1998 to 2007, there was a significant 60% increase in TEVAR cases performed for TAA. Similarly, TEVAR for TAD reportedly increased from 0.03 per 100,000 cases in 2000 to 0.8 per 100,000 cases in 2010.[5] Even with its advantages, associated major postoperative complications following TEVAR have been reported.[6-8] Understanding potential risk factors for morbidity and mortality is necessary to improve post-TEVAR outcomes.

Some studies have examined potential risk factors for post-TEVAR morbidity and mortality; however, no study to date has analyzed the relationship between resident involvement and TEVAR outcomes. The authors of this present study seek to assess resident participation as a potential risk factor for post-TEVAR morbidity and mortality using the large American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database.

MATERIALS AND METHODS

Data Source and Acquisition

The ACS-NSQIP database from 2010 to 2012 was queried. The ACS-NSQIP is a large national database of de-identified patient information collected from several participating hospitals in the United States. It was initially started as a quality improvement initiative for the Veteran's Administration (VA) healthcare system but has since expanded to include several other hospital system.[9] Data reported to the ACS-NSQIP is well-validated with high interrater reliability,[10] and consists of several preoperative, intraoperative, and 30-day postoperative patient variables.

Adult patients, 18 years and older, who underwent TEVAR were identified using current procedural terminology codes 33880, 33881, 33883, 33886, 33889, and 33891. Patients with missing intraoperative resident participation data were excluded. Additionally, variables that were not reported in all years analyzed were excluded.

Cases with resident participation were compared to those with no residents. Demographics, patient characteristics, and postoperative outcomes were analyzed.

Variable Definitions

Demographic variables analyzed included age, sex, and race (white, black, Asian, Native American Indian). Preoperative patient characteristics included body mass index, American Society of Anesthesiologists (ASA) class, dyspnea (at rest or moderate exertion), systemic sepsis (sepsis, septic shock, or systemic inflammatory response syndrome), diabetes (noninsulin dependent diabetes mellitus or insulin dependent diabetes mellitus), current smoker (within 1 y of surgery), functional health status $\leq$30 days before surgery (classified as independent, partially, or totally dependent), ventilator dependence $\leq$48 hours before surgery, history of chronic obstructive pulmonary disease $\leq$30 days before surgery, pneumonia, hypertension, history of chronic heart failure $\leq$30 days before surgery, history of myocardial infarction $\leq$6 months before surgery, previous of percutaneous coronary intervention, previous of cardiac surgery, history of angina $\leq$1 month before surgery, acute renal failure $\leq$24 hours before surgery, dialysis treatment $\leq$2 weeks before surgery, history of revascularization/amputation for peripheral vascular disease, history of transient ischemic attacks, cerebrovascular accidents or stroke with and without neurological deficits, wound infection, $\geq$10% loss of body weight in the last 6 months, bleeding disorder, and red blood cell (RBC) transfusion $\leq$72 hours before surgery.

Preoperative serum sodium, serum BUN, creatinine, albumin, total bilirubin, serum glutamic-oxaloacetic transaminase (SGOT), alkaline phosphatase, WBC, hematocrit, platelet count, prothrombin time, partial thromboplastin time, and international normalized ratio were also analyzed. For intraoperative variables, operative times and anesthesia times were analyzed.

Thirty-day postoperative outcome variables included mortality, pneumonia, prolonged mechanical ventilation $>$48 hours postsurgery, pulmonary embolism, stroke, coma $>$24 hours, urinary tract infections, progressive renal insufficiency, renal failure, myocardial infarction, cardiac arrest, deep venous thrombosis, RBC transfusions within 72 hours following surgery, sepsis, septic shock, wound and surgical site infections, and unplanned reintubation. Resident involvement was not documented in NSQIP after 2012.

Statistical Analysis

Data were analyzed using MedCalc Statistical Software version 17.9.7 (MedCalc Software, Ostend, Belgium). Descriptive statistics and binomial regression analysis of demographics, preoperative patient characteristics, operative details, and postoperative complications were conducted for all patients. Quantitative data were expressed as mean and standard deviation. Thirty-day postoperative morbidity and mortality were evaluated based on resident participation as an independent predictive variable of patient outcomes. p values of less than 0.05 were considered statistically significant. A post hoc power analysis was performed.

RESULTS

A total of 676 patients who underwent TEVAR from 2010 to 2012 were included for analysis. Of these, 517 (76.5%) had residents involved in their procedures. The majority of the cases analyzed (91.6%) were performed by vascular surgeons, 5.4% were performed by general surgeons, and 3% by general surgeons. There were little significant differences in demographics and preoperative patient characteristics. Notably, only smoking (32.9% vs 21.4%, $p < 0.01$), dyspnea on moderate exertion (21.5% vs 13.8%, $p = 0.03$), history of transient

TABLE 1. Demographics and Patient Characteristics Between Resident Involved and No Resident Involved TEVAR Groups

	No Resident Involved N = 159		Resident involved N = 517		
Demographics and Patient Characteristics	***N***	**(%)**	***N***	**(%)**	**p Value**
Age	68.9 (12.6)		68.8 (13.1)		0.92
Body mass index (BMI)	28.4 (6.1)		27.8 (6.2)		0.28
Sex					
Female	78	49.0	230	44.0	0.27
Male	81	51.0	278	53.0	
Race					
Black	23	14.0	88	17.0	0.37
White	118	74.0	350	68.0	0.15
Native American	0	0	5	0.1	0.71
Asian	8	5.0	22	4.0	0.58
Dyspnea at rest	6	3.8	22	4.3	0.79
Dyspnea on moderate exertion	22	13.8	111	21.5	0.03
Sepsis	13	8.2	34	6.6	0.49
Septic shock	0	0	3	0.1	0.76
SIRS	10	6.3	28	5.4	0.68
Diabetes					
Insulin dependent	4	2.5	21	4.0	0.38
Noninsulin dependent	14	8.8	45	8.7	0.97
Smoking	34	21.4	170	32.9	<0.01
Smoking >15 y	58	36.5	193	37.3	0.84
RBC transfusions	5	3.1	24	4.6	0.41
Wound infection	7	4.4	15	2.9	0.35
Bleeding disorder	10	6.3	58	11.2	0.07
Paraplegia	3	1.9	13	2.5	0.65
Weight loss	4	2.5	17	3.3	0.62
ASA classifications					
ASA I-III	69	43.4	263	50.9	0.10
ASA > III	87	54.7	250	48.4	0.16
Functional health status before surgery					
Independent	2	1.3	16	3.1	0.21
Partially dependent	12	7.5	32	6.2	0.54
Totally dependent	14	8.8	48	9.3	0.85
Ventilator dependence	2	1.3	22	4.3	0.07
History of severe COPD	21	13.2	102	19.7	0.06
Current pneumonia	4	2.5	7	1.4	0.31
Congestive heart failure (CHF) in 30 d before surgery	1	0.1	11	2.2	0.07
History of myocardial infarction 6 mo before surgery	3	1.9	14	2.7	0.56
Previous percutaneous coronary intervention	20	12.6	66	12.8	0.95
Previous cardiac surgery	27	17.0	111	21.5	0.22
History of angina in 1 mo before surgery	9	5.7	29	5.6	0.98
Hypertension requiring medication	138	86.8	450	87	0.95
History of revascularization/amputation for peripheral vascular disease	15	9.4	44	8.5	0.72
Acute renal failure	3	1.9	5	1.0	0.35
Currently on dialysis	5	3.1	13	2.5	0.67
Hemiplegia	5	3.1	9	1.7	0.28
History of transient ischemic Attacks	17	10.7	27	5.2	0.01
CVA/stroke with neurological deficits	18	11.3	32	6.2	0.03
CVA/stroke with no neurological deficits	9	5.7	21	4.1	0.39

COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; SIRS, systemic inflammatory response syndrome.

TABLE 2. Preoperative Laboratory (Lab) Variables

Preoperative Laboratory Values	No Resident Involved N = 159		Resident Involved N = 517		p Value
	N	(%)	N	(%)	
Serum sodium <135 mEq/L	18	11.3	59	11.4	0.98
Serum BUN <23 mg/dL	40	25.2	128	24.8	0.92
Serum creatinine <1.1 mg/dL	63	39.6	187	36.2	0.43
Serum albumin <3.5 g/dL	49	30.8	155	30.0	0.84
Total bilirubin <1.2 mg/dL	10	6.3	28	5.4	0.68
Aspartate aminotransferase, SGOT <35 U/L	15	9.4	44	8.5	0.72
Alkaline phosphate <126 U/L	7	4.4	37	7.2	0.22
WBC $<4.5 \times 10^9$/L	35	22.0	118	22.8	0.83
Hematocrit <34%	51	32.1	170	32.9	0.85
Platelet count $<150 \times 10^3/\mu$L	26	16.4	95	18.4	0.56
PTT <34.9 sec	30	18.9	76	14.7	0.21
International normalized ratio (INR) values <1.5	8	5.0	27	5.2	0.92
PT <14.9 sec	24	15.1	92	17.8	0.43

PT, prothrombin time; PTT, partial thromboplastin time.

ischemic attack (10.7% vs 5.2%, p = 0.01), and cerebrovascular accidents or stroke with neurological deficits (11.3% vs 6.2%, p = 0.03) appeared to be statistically significant. Demographic and preoperative patient characteristics between the 2 groups are shown in Table 1.

Similarly, preoperative laboratory variables between 2 groups showed no statistically significant differences (Table 2).

In addition, results from Table 3 demonstrate that operative time (176.1 ± 122.8 min vs 180.3 ± 119.1 min, p = 0.71) and anesthesia time (282.1 ± 146.6 min vs 278.3 ± 140.5 min, p = 0.78) were not statistically significant. In fact, the number of patients with operative times over 240 minutes (78.3% vs 79.9%, p = 0.68) and anesthesia times over 300 minutes (63.8% vs 63.5%, p = 0.95) were similar between the 2 groups.

Table 4 summarizes results for all postoperative outcome variables analyzed between patients who had residents involved in their procedures and those who did not. The overall mortality rate was 9.8%, with no significant differences in mortality (9.5% vs 10.7%, p = 0.65) between the 2 groups. Resident involvement in TEVAR procedures was not found to be a significant predictor of postoperative morbidity. Postoperative pneumonia (3.5% vs 6.9%, p = 0.06), prolonged mechanical ventilation (11.8% vs 11.9%, p = 0.96), pulmonary embolism (0.8% vs 0%, p = 0.27), stroke (2.7% vs 5.7%, p = 0.07), coma >24 hours (1.2% vs 0%, p = 0.17), urinary tract infections (3.3% vs 4.4%, p = 0.50), progressive renal insufficiency (1.2% vs 2.5%, p = 0.22), acute renal failure (4.1% vs 5.0%, p = 0.60), cardiac arrest (2.9% vs 5.0%, p = 0.20), myocardial infarction (1.7% vs 1.9%, p = 0.91), deep venous thrombosis (1.7% vs 1.3%, p = 0.67), RBC transfusions within 72 hours following surgery (29.2% vs 36.5%, p = 0.08), sepsis (2.9% vs 4.4%, p = 0.35), septic shock (1.9% vs 3.8%, p = 0.18), and unplanned reintubation (8.7% vs 9.4%, p = 0.78) were not significant predictors of complications. Wound and surgical site infections were also not statistically significant between the 2 groups.

Post hoc power analysis suggested a 34% chance of a type II error at a significance of $p < 0.05$.

DISCUSSION

Resident participation in surgery is necessary for surgical training. However, providing an optimal learning experience without compromising patient experience and

TABLE 3. Anesthesia and Operative Times Between the 2 Groups

Anesthesia/Operative Times	No Resident Involved N = 159		Resident Involved N = 517		p Value
	N	(%)	N	(%)	
Anesthesia time (min)	278.3 (140.5)		282.1 (146.6)		0.78
Anesthesia time >300 min	101	63.52	330	63.82	0.95
Operative time (min)	180.2 (119.1)		176.1 (122.8)		0.71
Operation time >240 min	127	79.87	408	78.33	0.68

TABLE 4. Thirty-Day Postoperative Outcomes

Postoperative Outcomes	No Resident Involved N = 159		Resident Involved N = 517		p Value
	N	(%)	N	(%)	
Infected wound	1	0.6	0	0	0.07
Cardiac arrest	8	5.0	15	2.9	0.20
Unplanned reintubation	15	9.43	45	8.7	0.78
Prolonged mechanical ventilation	19	11.9	61	11.8	0.96
Surgical site infection	1	0.6	2	0.4	0.69
Urinary tract infection (UTI)	7	4.4	17	3.3	0.50
Pneumonia	11	6.9	18	3.5	0.06
RENAINSF	4	2.5	6	1.2	0.22
Renal failure	8	5.0	21	4.1	0.60
Pulmonary embolism	0	0	4	0.8	0.27
Stroke	9	5.7	14	2.7	0.07
Myocardial infarction	3	1.9	8	1.7	0.91
RBC transfusions	58	36.5	151	29.2	0.83
Coma	0	0	6	1.2	0.17
DVT	2	1.3	9	1.7	0.67
Systematic sepsis	7	4.4	15	2.9	0.35
Septic shock	6	3.8	10	1.9	0.18
Mortality	17	10.7	49	9.5	0.65

DVT, deep venous thrombosis.

surgical outcomes can be challenging. The current graduate surgical training provides a system of graduated responsibility that over time makes residents sufficiently skilled and well-equipped.[11] Surgical residents undergo a learning curve as they acquire new surgical skills while being tasked with providing safe, high-quality care to patients. With the continued shift toward improving patient outcomes, it becomes necessary to consider the effect that residents have when involved in surgery.

The effect of resident participation in surgery is controversial. Though a large proportion of literature in some surgical subspecialties have observed resident participation to be relatively safe,[12-18] others have found significant increase in postoperative morbidity and mortality.[11,19-22] In the field of cardiovascular surgery, a paucity of studies exist that evaluate the effect of resident participation on surgical outcomes. To the best of the authors' knowledge, it is unknown whether resident participation in TEVAR affects postoperative outcomes. This present study used the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database to provide a comparative analysis on the effect of resident participation on postoperative morbidity and mortality in 679 TEVAR patients.

Overall, resident participation in TEVAR was not significantly associated with major postoperative complications and mortality. This finding corroborates previous reports that used ACS-NSQIP database to evaluate postoperative outcomes associated with resident participation in surgical procedures and observed no significant increase in major morbidity.[12-14,23-25] Additionally, operative time was not remarkably prolonged, unlike as observed in some studies.[11,12]

When analyzing the effect of resident participation on surgical outcomes, Raval et al.[26] suggest 3 essential factors that need to be considered. These include: (1) increased operative time that results from technical intraoperative complications due to resident participation; (2) unmeasured case-mix differences between procedures that involve residents and those that do not, with a larger number of resident-involved cases occurring at teaching hospitals which usually serve as referral centers for complex patients or procedures; and (3) increased postoperative vigilance through overuse of laboratory tests or imaging when residents are involved in cases. Taking all 3 considerations into account, it is not surprising that some prior studies found unfavorable postoperative outcomes when residents participated in surgeries.

Still, with appropriate provisions that allow residents to efficiently assist during surgery, resident participation does not only serve to benefit surgical training, but also becomes essential for patient survival. Raval et al.[26] report a 1.4 decrease in mortality per 1000 general and vascular surgery cases while Ejaz et al.[25] report a 25% decrease in perioperative mortality when residents are involved in surgical cases. The above studies corroborate results of this study that resident participation in TEVAR is relatively safe and should be encouraged.

It should be noted that analysis of this study did not allow for evaluation of reasons that accounted for the

favorable results observed when residents participated in TEVAR. The ACS-NSQIP database does not provide information on the level of resident supervision during surgery. Nevertheless, a provision that has been found to be beneficial and to successfully improve the technical skills of residents without compromising patient safety, regardless of amount of supervision received, is the use of simulators. Several studies that have evaluated the use of simulators in resident education have observed favorable results.[27-33] Generally, surgical residency education involves clinical or hands-on surgical learning interspersed with didactic lessons. These learning experiences, though essential, have been noted to have debatable effects on improving technical competence.[34,35] With simulation-based training, residents are given the opportunity to receive standard objective assessments, with little reliance on supervising attendings, while improving surgical techniques.[36] More importantly, skills acquired in simulators have been found to be transferable to the operating room.[36-39] The only noted downside to simulation-based training is cost.[32] That notwithstanding, the cost of poor patient outcomes due to insufficient resident training makes the use of simulators cost-effective.

Findings of this present study should be interpreted within the context of some limitations. First, the retrospective nature of the study made it difficult to prove causality, and to assess all essential preoperative comorbidities, postoperative course, and case complexity. Second, though the ACS-NSQIP database provides appropriate information that helps to address the role of resident participation in post-TEVAR complications, the database has some inherent limitations. The ACS-NSQIP only classifies cases based on current procedural terminology codes; hence, anatomical differences, procedural technique differences, and complication severity remain unclear. In addition, results may not be fully representative of all US hospitals since the ACS-NSQIP database over-represents data from academic institutions. Moreover, the ACS-NSQIP database does not provide information on contributing hospitals, making it difficult to adjust for institution size, patient volume, academic affiliation, and surgeon procedural experience. Similarly, although the ACS-NSQIP database provides information on the participation of surgical residents in surgery, involvement of nonsurgical residents, staff or students is not provided. The degree of involvement of surgical residents in the operating room and during the perioperative period is also not provided. Furthermore, the ACS-NSQIP database only provides information on 30 days postoperative complications, so long-term complications were not analyzed, potentially leading to underestimation of some outcome variables. Lastly, it should be noted that although the ACS-NSQIP provides the largest available public database to determine the effect of resident participation on post-TEVAR outcomes, the findings of this study could still represent a type II error if our sample size is underpowered. The post hoc power analysis of overall complication rates based on resident participation and postoperative complications was small but not insignificant.

Despite these limitations, this study does describe the effect of resident involvement on post-TEVAR outcomes. Future studies should strive to assess long-term postoperative outcomes associated with resident participation.

CONCLUSION

Surgical residents play an integral part of patient care and continuity of care. Each resident trained represents the future generation of surgery. However, training residents should not undermine patient safety and outcomes. In analysis of patients who underwent TEVAR using the large national ACS-NSQIP database, this present study found that resident participation did not significantly affect 30-day patient outcomes in all domains. As such, though resident participation may be tasking, the learning curve that residents go through to achieve acceptable levels of competence does not negatively affect operative outcomes. Resident involvement in TEVAR is thus relatively safe and should be encouraged.

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