Nationwide trends and regional/hospital variations in open versus endovascular repair of thoracoabdominal aortic aneurysms

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Objectives: Thoracic endovascular aortic repair (TEVAR) has been gaining popularity for the treatment of thoracoabdominal aortic aneurysm (TAAA). We used a nonvoluntary database to examine national trends and regional/hospital variations in the use of TEVAR and open thoracic aortic repair (OTAR) for TAAA.

Methods: From the 2005-2008 Nationwide Inpatient Sample database, we identified all patients with the diagnosis of TAAA who were treated with TEVAR or OTAR. Rates of these procedures were compared between years, across geographic regions, and between hospitals of various bed sizes.

Results: Over the study period, the rate of OTAR remained relatively stable (range, 7.5/100 patients in 2005 to 10.1/100 patients in 2008; $P = .26$), whereas the rate of TEVAR increased dramatically (range, 1.4/100 patients in 2005 to 6.3/100 patients in 2008; $P < .0001$). In 2008, 29% (211) of all TEVAR procedures and 11% (130) of all OTAR procedures were performed in western regions of the United States ($P = .03$). Additionally, 13% (95) of all TEVAR procedures and 3% (35) of all OTAR procedures were performed in smaller hospitals ($P < .0001$).

Conclusions: The use of TEVAR for TAAA repair increased significantly over the study period, whereas OTAR rates remained relatively stable. Our findings suggest that more patients who were otherwise not surgical candidates or did not have traditional surgical indications for OTAR were treated with TEVAR, most commonly in regions or hospitals where OTAR is less often performed. Given the complexity of TAAA cases, these results may have significant implications for patient safety in the current era of heightened health care scrutiny. (J Thorac Cardiovasc Surg 2012;144:612-6)

After endovascular techniques were developed for the management of abdominal aortic aneurysms in 1991, they competed with open aortic repair and have become the primary treatment modality for many patients with isolated aortic aneurysms.¹⁻³ Endovascular interventions for aneurysm repair were further refined after the technology for thoracic endovascular aortic repair (TEVAR) was approved by the US Food and Drug Administration in 2005 for use in the repair of thoracic aortic aneurysms,⁴ leading to an increased use of stent grafts in repairing some thoracic aortic aneurysms. Since then, TEVAR has been rapidly gaining popularity.

Preliminary short-term data regarding the use of TEVAR to treat thoracic aortic aneurysms have been promising.⁵ Intermediate outcomes for TEVAR in the treatment of thoracic aortic aneurysms, first described in several single-center studies,⁶ were further elucidated in a nationwide study that aimed to

address TEVAR's national utility and that associated TEVAR with better in-hospital outcomes, shorter lengths of stay, and fewer complications than open thoracic aortic repair (OTAR).⁷

Thoracoabdominal aortic aneurysm (TAAA) is a rare but complex and potentially lethal disease with relatively high perioperative morbidity and mortality. Historically, TAAA has required open surgical repair.^{8,9} The overall rupture rate is estimated to be as high as 26%,¹⁰ and rupture is associated with an overall mortality rate of 20.3%.¹¹ Postrepair and perioperative mortality rates from experienced centers range from approximately 4% to 16%.¹²⁻¹⁶ Given the relatively high morbidity and mortality of open surgical TAAA repair, less-invasive TEVAR procedures with adjunctive surgical visceral vessel debranching (hybrid approach) and TEVAR alone with specialized branched endografts have slowly emerged as feasible and promising alternatives.¹⁷⁻²⁰

However, little is known about regional and hospital variation in the use of TEVAR for the treatment of TAAA. We examined nationwide trends and attempted to determine whether there is any regional or hospital variation in the use of TEVAR versus OTAR for the treatment of TAAA.

MATERIALS AND METHODS

Data Source

Data were collected from the 2005-2008 Nationwide Inpatient Sample (NIS). The NIS is a database of hospital inpatient stays and is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project (HCUP).²¹ The NIS is the largest all-payer

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Abbreviations and Acronyms

HCUP	= Healthcare Cost and Utilization Project
ICD-	= International Classification of Diseases,
9-CM	Ninth Revision, Clinical Modification
NIS	= Nationwide Inpatient Sample
OTAR	= open thoracic aortic repair
TAAA	= thoracoabdominal aortic aneurysm
TEVAR	= thoracic endovascular aortic repair

inpatient care database, representing 20% of all hospital discharges from nonfederal facilities within the United States. The NIS has numerous internal quality assurance procedures that check the consistency and validity of data points (<http://www.hcup-us.ahrq.gov/db/quality.jsp>). Furthermore, HCUP validates the NIS annually by comparing its contents with those of 2 similar databases, the National Hospital Discharge Survey and the Medicare Provider Analysis and Review, to assess potential biases in the dataset (<http://www.hcup-us.ahrq.gov/db/nation/nis/nisrelatedreports.jsp>). The NIS contains data on approximately 8 million hospital stays each year from more than 1000 hospitals. Weights based on sampling probabilities for each stratum are used in the analysis to ensure that the hospitals studied are representative of all US hospitals. Five hospital sampling strata were defined according to hospital characteristics contained in the American Hospital Association Annual Survey of Hospitals. The stratification variables were geographic region ([Appendix Table 1](#)), location (urban or rural), teaching status, control (public or proprietary), and bed size ([Appendix Table 2](#)).

This study was approved by the Institutional Review Board of Baylor College of Medicine. The reported data conform to the data-use agreement for the NIS from the HCUP. Additional information about NIS is available from the Agency for Healthcare Research and Quality, which administers the database as part of the HCUP (<http://www.hcup-us.ahrq.gov/nisoverview.jsp>).

Patient Selection

Patient identification was based on the 2008 International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes.²² We used these codes to query the 2005-2008 NIS database for our patient selection. The ICD-9 diagnosis codes 4416 and 4417 were used to identify all patients with TAAA. Within this group of patients, the ICD-9 procedure codes 3835 and 3845 were used to identify patients who underwent OTAR only without any endovascular intervention, and procedure code 3973 was used to identify patients who underwent TEVAR with or without a hybrid debranching procedure. We excluded patients who underwent both TEVAR and OTAR during the same index hospitalization in an attempt to exclude emergency open conversions from our final analysis.

We found a total of 39,135 records of patients with the diagnosis of TAAA who were discharged from a hospital during the 4-year study period. Of these patients, 2911 underwent OTAR only, and 1838 underwent TEVAR alone with branched endografts or TEVAR with a hybrid visceral debranching procedure.

Statistical Analysis

NIS database discharge weights were used to produce national estimates for all analyses. Rates of TEVAR and OTAR were then compared by year, geographic region ([Appendix Table 1](#)), and hospital bed size ([Appendix Table 2](#)) by using the Rao-Scott χ^2 test. All data were analyzed with SAS/STAT software, version 9.1, of the SAS System for the XP PRO platform (SAS Institute Inc, Cary, NC).

RESULTS

As shown in [Figure 1](#), the rate of OTAR remained relatively stable over the study period (7.5/100 TAAA patients in 2005 vs

10.1/100 TAAA patients in 2008; $P = .26$). In contrast, the rate of TEVAR increased significantly, from 1.4/100 TAAA patients in 2005 to 6.3/100 TAAA patients in 2008 ($P < .0001$).

In the most recent data set (from 2008), 29% of all TEVAR procedures were performed in western regions of the United States (as defined in [Appendix Table 1](#)), whereas only 11% of all OTAR procedures were performed in those regions ([Table 1](#)). Similarly, in 2008, 13% of all TEVAR procedures were performed in small bed size hospitals (as defined in [Appendix Table 2](#)), whereas only 3% of all OTAR procedures were performed in small hospitals ([Table 2](#)).

DISCUSSION

We found that whereas OTAR rates remained relatively stable over the 4-year study period, TEVAR rates significantly increased over the same period for the treatment of TAAA. Moreover, the rates of TEVAR and OTAR varied among regions and by hospital bed size, in that more TEVAR procedures than OTAR procedures were performed in western regions of the United States and in smaller hospitals across the country.

Because of both the minimal invasiveness of TEVAR compared with OTAR and patient-driven demand for TEVAR technology, TEVAR rates for the treatment of TAAA rapidly increased between 2005 and 2008, whereas rates of OTAR for TAAA remained relatively unchanged during the same period. Although these results are not unexpected, the regional and hospital variation in the use of these procedures is a novel finding and may have significant implications.

Open surgical TAAA repairs are complex surgical procedures, the outcomes of which have been shown to be best at high-volume centers with high-volume surgeons.²³ For this reason, OTAR for TAAA repair often requires a dedicated team of surgeons, anesthesiologists, ancillary support staff, and hospital resources to achieve optimal outcome. Although TEVAR is less invasive than OTAR, intraoperative conversion to emergency OTAR—the probability of which is not insignificant—carries a high mortality and morbidity rate.²⁴

Our study shows significant regional and hospital variation in the rates of TEVAR and OTAR procedures for the treatment of TAAA. Specifically, a higher percentage of TEVAR procedures than OTAR procedures was performed in western regions of the United States and in smaller hospitals ([Tables 1 and 2](#)). When complications from TEVAR procedures occur in regions or hospitals where OTAR is less commonly performed, emergency open conversion must be done in a setting where resources and experience may be limited. This situation is probably not uncommon, because conversion to OTAR is necessary in approximately 4% of TEVAR procedures performed to treat thoracic aortic disease of any sort.²⁴ The outcomes of these emergency conversions may be compromised in such cases.

Regional variations in the rates of TEVAR identified in our study may have been due to population density variance

FIGURE 1. Nationwide trends in the rate of open versus endovascular repair of thoracoabdominal aortic aneurysm (TAAA). TEVAR, Thoracic endovascular aortic repair; OTAR, open thoracic aortic repair.

across different census tracts of the United States. Specifically, western and northeastern regions account for approximately 22% and 17% of the overall US population, respectively (www.census.gov/prod/cen2010/briefs/c2010br-01.pdf). Assuming equal prevalence of TAAA across the country, each of these 2 regions are performing 7% more TEVAR than expected when compared with their population densities (Table 1). Along the same line of reasoning, the western region is performing 11% fewer OTAR procedures while the northeastern region is performing 20% more OTAR procedures (Table 1). Even after adjusting for population density differences, our study continued to support the observation that TEVAR procedures are being performed more commonly in regions (such as the west) where OTAR is less often performed. This observation along with hospital variation in TEVAR/OTAR procedures ultimately may have significant patient safety implications, as previously suggested.

Our study is subject to the limitations inherent in a retrospective review and in the use of an administrative database like that of the NIS. As such, we were not able to obtain specific operative procedure details (pure endograft vs hybrid) or clinical outcome information, and there may have been reporting bias owing to coding errors. However, the focus of our study was on the health-service implications of trends in TEVAR and OTAR use, not on clinical outcomes, and any potential reporting bias would have been equally distributed between the TEVAR and OTAR cases. Also, although the NIS database provides a significant amount of information on hospital characteristics, it does not adjust for the volume

of cases performed by individual surgeons, nor does it include specific data regarding the anatomic extent of each patient's TAAA. Nonetheless, the large sample size of our database allowed us to identify significant regional and hospital variations. Also, the nonvoluntary nature of the NIS database provides a novel "real-world" snapshot of TEVAR/OTAR trends and variations in the treatment of TAAA.

Future research efforts should focus on exploring the mechanisms underlying these regional and hospital variations. Previous research has suggested that regionalizing procedures associated with high perioperative mortality rates such as open surgical TAAA repair and endovascular repair for ruptured abdominal aortic aneurysms would improve outcomes.^{23,25} However, it is unclear whether this would also be true for TAAA repairs with TEVAR. As TEVAR technology improves with the advent of customizable visceral branched endografts, the endovascular skills necessary for TAAA TEVAR may become increasingly difficult to master. Regionalization of TAAA patients to high-volume specialized aortic centers of excellence may be needed to achieve excellent outcomes and provide optimal patient safety.

In conclusion, our results suggest that there are significant national trends and variations in the use of TEVAR versus OTAR for TAAA repair, and these differences may have important health care and patient safety implications. Further work is needed to identify the mechanisms that underlie these observed variations and to determine what implications these disparities have for patient outcomes.

TABLE 1. Regional variation in the treatment of thoracoabdominal aortic aneurysms in 2008

Procedure	Region				P value
	Northeast	Midwest	South	West	
OTAR	436 (37%)	353 (30%)	259 (22%)	130 (11%)	.03
TEVAR	176 (24%)	124 (17%)	219 (30%)	212 (29%)	

US geographic regions are those described on the Nationwide Inpatient Sample database Web site (http://www.hcup-us.ahrq.gov/db/vars/h_region/nisnote.jsp). OTAR, Open thoracic aortic repair; TEVAR, thoracic endovascular aortic repair.

TABLE 2. Hospital variation in the treatment of thoracoabdominal aortic aneurysms in 2008

Procedure	Hospital bed size			P value
	Small	Medium	Large	
OTAR	35 (3%)	47 (4%)	1096 (93%)	<.0001
TEVAR	95 (13%)	80 (11%)	556 (76%)	

Hospital bed size categories are those described on the Nationwide Inpatient Sample database Web site (http://www.hcup-us.ahrq.gov/db/vars/hosp_bedsizes/nisnote.jsp). OTAR, Open thoracic aortic repair; TEVAR, thoracic endovascular aortic repair.

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APPENDIX TABLE 1. Geographic regions

Geographic region	States
Northeast	ME, NH, VT, MA, RI, CT, NY, NJ, PA
Midwest	OH, IN, IL, MI, WI, MN, IA, MO, ND, SD, NE, KS
South	DE, MD, DC, VA, WV, NC, SC, GA, FL, KY, TN, AL, MS, AR, LA, OK, TX
West	MT, ID, WY, CO, NM, AZ, UT, NV, WA, OR, CA, AK, HI

US geographic regions are those described on the Nationwide Inpatient Sample database Web site (http://www.hcup-us.ahrq.gov/db/vars/h_region/nisnote.jsp).

APPENDIX TABLE 2. Hospital bed size

Location and teaching status	Hospital bed size		
	Small	Medium	Large
Northeast region			
Rural	1-49	50-99	100+
Urban, nonteaching	1-124	125-199	200+
Urban, teaching	1-249	250-424	425+
Midwest region			
Rural	1-29	30-49	50+
Urban, nonteaching	1-74	75-174	175+
Urban, teaching	1-249	250-374	375+
Southern region			
Rural	1-39	40-74	75+
Urban, nonteaching	1-99	100-199	200+
Urban, teaching	1-249	250-449	450+
Western region			
Rural	1-24	25-44	45+
Urban, nonteaching	1-99	100-174	175+
Urban, teaching	1-199	200-324	325+

Hospital bed size categories are those described on the Nationwide Inpatient Sample database Web site (http://www.hcup-us.ahrq.gov/db/vars/hosp_bedsizes/nisnote.jsp).