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Outcomes and cost of open versus endovascular repair of intact thoracoabdominal aortic aneurysm

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ABSTRACT

Objective: Many previous studies have evaluated the outcomes of open and endovascular repair of thoracoabdominal aortic aneurysms (TAAAs). However, little is known about the differences in cost of these procedures and the potential factors driving these differences. The aim of this study was to evaluate the outcomes and cost of open aortic repair (OAR) vs endovascular repair of intact TAAA.

Methods: All patients undergoing repair for intact TAAA were identified in the Premier Healthcare Database (July 2009-March 2015). Categorical and continuous variables were analyzed using the χ^2 test, Student *t*-test, and median test as appropriate. A multivariable generalized linear model was used to examine total in-hospital cost.

Results: A total of 879 TAAA repairs were identified (481 [55%] endovascular repairs vs 398 [45%] OARs). Patients undergoing endovascular repair were on average 5 years older (71.2 [±10.0] years vs 66.5 [±10.9] years; $P < .001$) and more likely to be female (48% vs 42%; $P = .05$) and hypertensive (87% vs 80%; $P = .009$). Otherwise, there were no significant differences in comorbidities between the two groups. Patients undergoing OAR were more likely to stay longer in the hospital (median [interquartile range], 11 [7-20] days vs 5 [2-9] days; $P < .001$). In-hospital mortality (15% vs 5%; $P < .001$) and all major complications were two to three times higher after OAR. The median total cost of OAR was significantly higher compared with endovascular repair (cost [interquartile range], $44,355 [$32,177-$54,824] vs $36,612 [$24,395-$53,554]; $P = .004$). The majority of the cost attributed to TAAA repair was also higher in patients undergoing open repair: room and board ($11,561 vs $4720), operating room ($9230 vs $4929), pharmacy ($2309 vs $900), blood bank ($1189 vs $195), rehabilitation/physical therapy ($378 vs $236), and respiratory therapy ($875 vs $168; all $P < .001$). Only the cost of central supplies, which includes endovascular grafts and stents, was the highest among patients undergoing endovascular repair ($17,472 vs $5501; $P < .001$). The cost of diagnostic imaging ($625 vs $595) and anesthesia ($479 vs $478) was similar in both approaches. In a multivariable analysis, the adjusted total hospitalization cost for OAR was $5974 (95% confidence interval, $1828-$10,120; $P = .005$) higher compared with endovascular repair. However, after adjusting for in-hospital complications, no difference was seen between the two approaches (−$460; 95% confidence interval, −$4390 to $3470; $P = .82$).

Conclusions: In this large cohort of intact TAAAs, we showed a significantly higher adjusted total hospitalization cost of open compared with endovascular repair despite the additional cost of endografts. This is likely driven by longer length of stay and higher morbidity after OAR. (J Vasc Surg 2018;■:1-8.)

Keywords: Open repair; Endovascular repair; TAAA; Aneurysm; Premier

Repair of thoracoabdominal aortic aneurysms (TAAAs) remains a challenging procedure in vascular surgery associated with an increased morbidity and mortality. In 1955, Etheredge et al[1] performed the first successful TAAA repair in the United States. Since then, despite marked surgical advancement in managing aneurysms, the mortality after TAAA repair remains relatively high. In our recently published work involving ruptured TAAA, we demonstrated an increased mortality of 38% and 26% after open aortic repair (OAR) and endovascular repair, respectively ($P = .09$).[2]

OAR has been the "gold standard" in managing TAAA for many years. With the advent of thoracic aortic stent grafting,[3] endovascular repair of thoracic aortic aneurysms (TAAs) became a promising alternative to open repair. The recent advancement in endovascular techniques, such as snorkel, sandwich, and surgeon-modified endografts, and the development of

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fenestrated and branched endografts have allowed vascular surgeons to treat high-risk patients with complex TAAA anatomy.[4,5] The U.S. Food and Drug Administration first approved thoracic endografts and fenestrated endografts in 2005[6] and 2012,[7] respectively. There are several ongoing investigational device exemption studies evaluating branched and surgeon-modified endografts. Published studies comparing the outcomes of endovascular and open repair of TAA[8,9] and TAAA[5,10,11] revealed promising results for endovascular repair and reported lower morbidity, shorter hospital stay, and improved aneurysm-related mortality, although none has been a randomized study.

Very few studies have reported the cost of TAAA repair. Earlier studies on TAA and abdominal aortic aneurysm showed increased endovascular costs related to the endografts and increased reinterventions. In contrast, the cost of open repair has largely been driven by the increased length of stay and hospital-related charges, such as medications and laboratory testing.[12-16] In spite of the expected favorable outcomes after minimally invasive endovascular repair, the benefits of this approach in managing TAAA may be overshadowed by the higher costs of the endografts and stents needed for the repair. With the recent focus on cost reduction in health care, these new emerging technologies will face resistance from hospitals and insurance providers. Thus, the main aim of this study was to compare the outcomes and costs of patients undergoing endovascular vs open repair for nonruptured TAAA in the United States.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of prospectively collected data from the Premier Healthcare Database
- **Take Home Message:** In 879 patients with intact thoracoabdominal aortic aneurysms, endovascular repair compared with open repair resulted in significantly lower mortality rates (5% vs 15%), shorter hospital stays (5 vs 11 days), and lower overall costs despite the high cost of the stent graft.
- **Recommendation:** This study suggests that endovascular repairs of intact thoracoabdominal aortic aneurysms have better results and lower overall costs than open repairs.

METHODS

Study design and database. We conducted a retrospective study using the Premier Healthcare Database (PHD),[17] a large U.S. hospital-based, all-payer data set that contains data from >700 U.S. participating hospitals with >80 million total inpatient admissions, with >6 million per year since 2011 (approximately 20% of annual U.S. inpatient discharges). It contains information primarily from geographically diverse nonprofit, nongovernmental, community and teaching hospitals from both urban and rural areas. The PHD offers deidentified, Health Insurance Portability and Accountability Act-compliant data from standard hospital discharge billing files. Descriptive data on patients' demographic characteristics, costs, length of stay, hospital location, and mortality are also readily available in this data set. In the PHD, costs are those reported by the hospital and represent the hospital's internal cost accounting systems. Cost data are thoroughly reviewed and validated before they are used in the PHD. Premier also performs reconciliation, comparing data the hospital has submitted with the hospital's financial statement. If issues are identified, Premier works with the hospitals to update and to correct the data. Once the data are resubmitted to Premier, stringent data processing and validation are again undertaken. The data on index procedure and outcomes were obtained using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) procedure and diagnosis codes, which are also provided in the PHD. The Institutional Review Board approved this study with exemption from consent of individual patients because it includes only deidentified data.

Study population. We identified all patients with a primary and admitting diagnosis of nonruptured TAAA using ICD-9-CM diagnosis code 441.7 between July 2009 and March 2015. ICD-9-CM procedural codes were then matched with the diagnosis codes of nonruptured TAAA to identify patients undergoing OAR (38.44, 38.45, and 39.25) and endovascular repair (39.71, 39.73, and 39.78). Any patient with concomitant OAR and endovascular repair was excluded from the study.

Covariates. Patients' demographics and regional characteristics included age, sex, race, insurance, hospital location, and teaching status. Medical comorbidities and Charlson Comorbidity Index were identified using respective ICD-9-CM diagnosis codes as listed in Supplementary Table I (online only). Patients' discharge status, home vs nonhome (including nursing home, skilled nursing facility, and other institutions), was also identified in the PHD.

Outcomes. The primary outcome of interest was in-hospital mortality. Secondary outcomes included acute renal failure, pulmonary complications (pneumonia, respiratory failure, ventilator support), paraplegia/spinal cord ischemia, stroke, and cardiac complications (myocardial infarction and arrhythmia). ICD-9-CM diagnosis codes used to identify the secondary outcomes are provided in Supplementary Table II (online only).

In-hospital cost. The PHD is an appropriate data set to use in analyzing hospitalization costs of any surgical