Southwestern Surgical Congress

Outcomes of endovascular management of acute thoracic aortic emergencies in an academic level 1 trauma center

Angela B. Echeverria, M.D., Pharm.D., Bernardino C. Branco, M.D., Kay R. Goshima, M.D., John D. Hughes, M.D., Joseph L. Mills, Sr, M.D.*

Department of Surgery, Division of Vascular and Endovascular Surgery, Department of Surgery, University of Arizona, 1501 North Campbell Avenue, PO Box 245072, Tucson, AZ 85724-5072, USA

KEYWORDS: Acute aortic emergencies; TEVAR; Outcomes; Mortality

Abstract

BACKGROUND: Thoracic aortic emergencies account for 10% of thoracic-related admissions in the United States and remain associated with high morbidity and mortality rates. Open repair has declined owing to the emergence of thoracic endovascular aortic repair (TEVAR), but data on emergency TEVAR use for acute aortic pathology remain limited. We therefore reviewed our experience.

METHODS: We retrospectively evaluated emergency descending thoracic aortic endovascular interventions performed at a single academic level 1 trauma center between January 2005 and August 2013 including all cases of traumatic aortic injury, ruptured descending thoracic aneurysm, penetrating atherosclerotic ulcer, aortoenteric fistula, and acute complicated type B dissection. Demographics, clinical data, and outcomes were extracted. Stepwise logistic regression was used to identify independent risk factors for death.

RESULTS: During the study period, 51 patients underwent TEVAR; 22 cases (43.1%) were performed emergently (11 patients [50.0%] traumatic aortic injury; 4 [18.2%] ruptured descending thoracic aneurysm; 4 [18.2%] complicated type B dissection; 2 [9.1%] penetrating aortic ulcer; and 1 [4.5%] aortoenteric fistula). Overall, 72.7% (n = 16) were male with a mean age of 54.8 ± 15.9 years. Nineteen patients (86.4%) required only a single TEVAR procedure, whereas 2 (9.1%) required additional endovascular therapy, and 1 (4.5%) open thoracotomy. Four traumatic aortic injury patients required exploratory laparotomy for concomitant intra-abdominal injuries. During a mean hospital length of stay of 18.9 days (range, 1 to 76 days), 3 patients (13.6%) developed major complications. In-hospital mortality was 27.2%, consisting of 6 deaths from traumatic brain injury (1); exsanguination in the operating room before repair could be achieved (2); bowel ischemia (1) and multisystem organ failure (1); and family withdrawal of care (1). A stepwise logistic regression model identified 24-hour packed red blood cell requirements ≥4 units, admission mean arterial pressure <60 mm Hg, and...
24-hour fresh frozen plasma to packed red blood cell (pRBC) ratio <1:1.5 as independent risk factors for death in this cohort. During a mean follow-up of 369 days (range, 35 to 957 days), no subsequent major complications or deaths occurred. All patients underwent serial computed tomographic angiography surveillance, and no device-related problems were identified during intermediate follow-up.

CONCLUSIONS: Thoracic aortic emergencies remain challenging. Our experience in a moderate-volume center supports the utilization of TEVAR in the acute setting. Twenty-four-hour pRBC requirements ≥4 units, admission mean arterial pressure <60 mm Hg, and 24 hour fresh frozen plasma to pRBC ratio <1:1.5 were independently associated with death.

© 2014 Elsevier Inc. All rights reserved.

Aortic dissection and transection in blunt trauma with deceleration injury is not uncommon, accounting for up to 10% of trauma admissions in the United States, with a reported associated mortality as high as 45%. The patient population affected by blunt aortic injury experiences a high rate of complications including paraplegia, stroke, cardiac, renal, and respiratory failure.1,2

Until 2005, when the first thoracic endograft device was approved for use by the Food and Drug Administration, open operative repair was the norm, and yielded high morbidity and mortality. The technology of thoracic endovascular aortic repair (TEVAR) has emerged over the past 9 years as a minimally invasive approach to enable survival with decreased morbidity. TEVAR allows for a rapid control of hemorrhage and expeditious return of blood supply to end organs.2,3 There are limited available outcomes data across the broad spectrum of acute aortic pathology, aside from dissection and transection in trauma.

The purpose of this study was to evaluate the experience and outcomes in patients presenting with acute aortic catastrophes in a moderate-volume center.

Methods

After institutional review board approval was obtained, a retrospective review of all patients undergoing emergent TEVAR for acute surgical emergencies involving the descending thoracic aorta at the University of Arizona Medical Center between January 1, 2005 and August 31, 2013 was performed. We included patients with traumatic aortic injury, ruptured descending thoracic aneurysm, penetrating atherosclerotic ulcer, aortoenteric fistula, and acute complicated type B dissection. Patients with low-grade thoracic aortic injury managed nonoperatively were excluded.

Our center is described as a moderate-volume level 1 trauma center based on the guidelines of 1,200 trauma related admissions per year.1,5

Patient variables extracted included age, sex, ethnicity, body mass index, admission mean arterial pressure (MAP), and laboratory values such as hemoglobin and creatinine (Cr) levels, preoperative imaging studies (Fig. 1), surgical interventions, transfusion requirements in the first 24 hours after hospital admission, hospital length of stay, complications, and mortality. The types of aortic endograft used were also extracted. The primary outcome measures were technical success, defined as successful deployment of the stent graft at the intended targeted location and in-hospital mortality. Secondary outcomes included adverse events related to device, procedural and systemic complications, and 1-year survival. Patients were followed for postoperative complications and survival to their last clinic appointment visit or to the time of death.

All patients undergoing TEVAR at our institution are subjected to a close surveillance protocol consisting of clinical examination and contrast-enhanced computed tomography before discharge or at the 3-month follow-up appointment and then annually thereafter.

Descriptive statistics were used to report and analyze data. Values were reported as means ± standard deviation for continuous variables and as percentages for categorical variables. A second data analysis was carried out to compare survivors and nonsurvivors for differences in demographics, clinical data, and outcomes using bivariate analysis. Chi-square test was used to compare proportions, and unpaired Student t test was

Figure 1 (A, B, C) Selected CTA images before repair.
used to compare means. To identify independent risk factors for mortality in this cohort, factors that on bivariate analysis were significant at $P < .2$ were entered in a stepwise logistic regression model analysis. Data were entered into a computerized spreadsheet (Microsoft Excel 2003; Microsoft corporation, Redmond, WA) and analyzed using SPSS for Mac, version 19.0 (SPSS, Chicago, IL).

**Results**

During the study period, 51 patients underwent TEVAR; among those, 22 (43%) underwent emergent intervention for acute thoracic aortic syndromes (Fig. 2). There were 11 (50%) with traumatic aortic injury, 4 (18%) with ruptured descending thoracic aneurysm, 4 (18%) with complicated type B dissection, 2 (9%) with penetrating aortic ulcer, and 1 (4%) with aortoenteric fistula.

Overall, 73% ($n = 16$) were male, mean age was $54.8 \pm 15.9$ years, and 68% ($n = 15$) were Caucasian. Table 1 depicts the demographic features and clinical data of our study population according to primary aortic pathology. Patients with ruptured descending thoracic aneurysm were significantly more likely to be hypotensive on admission and to require higher transfusion volumes of packed red blood cell (pRBC) and fresh frozen plasma (FFP) in the first 24 hours (Table 1).

Table 2 depicts operative data among study groups. The Gore TAG (Gore, Flagstaff, AZ) was the most common type of endograft used in 50% ($n = 11$) of patients. Nineteen patients (86%) required only a single TEVAR procedure, whereas 2 (9%) required additional endovascular therapy. In 1 patient with ruptured descending thoracic aneurysm, the thoracic aortic endograft could not be deployed requiring conversion to an open thoracotomy. Four traumatic aortic injury patients required exploratory laparotomy for concomitant intra-abdominal injuries.

![Figure 2](A) Prerepair angiogram. (B) Postrepair angiogram.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographics and clinical data of the study population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traumatic aortic injury ($N = 11$)</td>
</tr>
<tr>
<td>Age (y), mean ± SD</td>
<td>43.3 ± 12.8</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>9 (81.8)</td>
</tr>
<tr>
<td>Caucasian, n (%)</td>
<td>9 (81.8)</td>
</tr>
<tr>
<td>BMI, kg/m², mean ± SD</td>
<td>28.2 ± 3.0</td>
</tr>
<tr>
<td>MAP on admission, mm Hg, mean ± SD</td>
<td>65.5 ± 15.2</td>
</tr>
<tr>
<td>MAP on admission &lt;60 mm Hg, n (%)</td>
<td>3 (27.3)</td>
</tr>
<tr>
<td>Hgb, g/dL level on admission, mean ± SD</td>
<td>11.8 ± 3.6</td>
</tr>
<tr>
<td>Cr, mg/dL level on admission, mean ± SD</td>
<td>1.2 ± 0.6</td>
</tr>
<tr>
<td>Cr level postoperative, mean ± SD</td>
<td>1.4 ± 0.4</td>
</tr>
<tr>
<td>24-Hour pRBC (units), mean ± SD</td>
<td>6.9 ± 5.1</td>
</tr>
<tr>
<td>24-Hour FFP (units), mean ± SD</td>
<td>3.0 ± 3.4</td>
</tr>
</tbody>
</table>

BMI = body mass index; Cr = creatinine; cTBD = complicated type B dissection; FFP = fresh frozen plasma; Hgb = hemoglobin level; MAP = mean arterial pressure; pRBC = packed red blood cells; rDTA = ruptured descending thoracic aneurysm; TAI = thoracic aortic injury; other = penetrating aortic ulcer and aortoenteric fistula.
Overall, in-hospital mortality was 27%. There were 6 deaths from traumatic brain injury (1); exsanguination in the operating room before repair could be achieved (2); bowel ischemia (1) and multisystem organ failure (1); and withdrawal of care by family (1). Three patients (14%) developed major complications (multisystem organ failure [1]; type A dissection or endoleak [1]; iliac and femoral aneurysms [2]). The mean hospital length of stay was 18.9 ± 19.0 days (Table 3).

When clinical data among survivors and nonsurvivors were compared, survivors were less likely to be hypotensive on admission (MAP < 60 mm Hg: 27% vs 71%; \(P < .001\)) and had lower transfusion requirements (pRBC: 3.9 ± 3.3 units vs 14.0 ± 5.8 units; \(P < .001\) and FFP: 1.5 ± 2.2 units vs 5.4 ± 2.8 units; \(P = .002\)). A stepwise logistic regression model identified 24-hour pRBC requirements (\(R \geq 4\) units), admission MAP < 60 mm Hg, and 24-hour FFP:pRBC ratio < 1:1.5 as independent risk factors for death in this cohort (Table 4).

During a mean follow-up of 369 ± 384 days (range, 35 to 957 days), no subsequent major complications or deaths occurred. All patients underwent serial computed tomography angiography (CTA) surveillance and no device-related problems were identified (Fig. 3).

**Comment**

The advent of TEVAR has revolutionized the treatment of acute aortic catastrophes. Technology and treatment paradigms continue to evolve. A recent study by Patel et al\(^4\) demonstrated that regardless of hospital volume, TEVAR can be safely performed; however, high-volume centers had improved outcomes for open repair compared with low-volume centers. Although TEVAR has been rapidly adopted and became the standard of care, owing to its recent introduction, outcomes beyond the short-term require assessment and evaluation. In the initial years of TEVAR, 2005 to 2007, the technology was FDA approved for limited indications. Over time, initially off-label uses have become approved indications.\(^5\),\(^6\)

---

**Table 2** Operative data according to study group

<table>
<thead>
<tr>
<th>TEVAR grafts</th>
<th>Traumatic aortic injury (N = 11)</th>
<th>Ruptured descending thoracic aneurysm (N = 4)</th>
<th>Complicated type B dissection (N = 4)</th>
<th>Other (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talent (Medtronic, Minneapolis, MN), n (%)</td>
<td>2 (18.2)</td>
<td>—</td>
<td>2 (50.0)</td>
<td>—</td>
</tr>
<tr>
<td>Zenith (Cook Medical, Bloomington, IN), n (%)</td>
<td>3 (27.3)</td>
<td>2 (50.0)</td>
<td>1 (25.0)</td>
<td>—</td>
</tr>
<tr>
<td>Gore TAG (Gore, Flagstaff, AZ), n (%)</td>
<td>6 (54.5)</td>
<td>1 (25.0)</td>
<td>1 (25.0)</td>
<td>3 (100.0)</td>
</tr>
<tr>
<td>Relay (Bolton Medical, Sunrise, FL), n (%)</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Other procedures</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Table 3** Outcomes

<table>
<thead>
<tr>
<th>In-hospital</th>
<th>Thoracic aortic injury (N = 11)</th>
<th>Ruptured descending thoracic aneurysm (N = 4)</th>
<th>Complicated type B dissection (N = 4)</th>
<th>Other (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death, n (%)</td>
<td>3 (27.3)</td>
<td>2 (50.0)</td>
<td>1 (25.0)</td>
<td>—</td>
</tr>
<tr>
<td>Multisystem organ failure, n (%)</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Aortic dissection, n (%)</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CFA thrombosis or aneurysm, n (%)</td>
<td>—</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
</tr>
<tr>
<td>Groin seroma or hematoma, n (%)</td>
<td>—</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
</tr>
<tr>
<td>Hospital length of stay (days), mean ± SD</td>
<td>22.2 ± 21.2</td>
<td>18.3 ± 21.8</td>
<td>15.0 ± 18.9</td>
<td>13.3 ± 8.1</td>
</tr>
<tr>
<td>At 1 year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death, n (%)</td>
<td>3 (27.3)</td>
<td>2 (50.0)</td>
<td>1 (25.0)</td>
<td>1 (33.3)</td>
</tr>
<tr>
<td>Type II endoleak, n (%)</td>
<td>—</td>
<td>1 (25.0)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

cTBD = complicated Type B dissection; HLOS = hospital length of stay; other = penetrating aortic ulcer and aortoenteric fistula; rDTA = ruptured descending thoracic aneurysm; TAI = thoracic aortic injury.
The literature boasts robust volumes with regard to blunt traumatic causes of acute aortic injury and TEVAR. The largest such TEVAR study in the literature was reported by Demetriades et al. This study included 193 patients with blunt thoracic aortic injury. The study found similar outcomes to our evaluation in TEVAR vs open patients (our present study did not evaluate open repair, as the number of patients was very small). But, if it needs to be covered and revascularization is necessary, we usually perform carotid subclavian bypass. The TEVAR group had lower blood transfusion requirements, hospital stay, and mortality. To our knowledge, this is the first TEVAR evaluation to investigate all acute pathology of the thoracic aorta including but not limited to traumatic mechanisms in a moderate-volume center. Prior studies tend to be trial study reports and included primarily patients undergoing TEVAR for trauma. The present study included cases of symptomatic penetrating ulcer, acute dissection, traumatic transection, and aneurysmal rupture.

Azizzadeh et al. suggested that TEVAR is associated with decreased blood transfusion requirements. In our primary outcomes, it was found that patients with increased transfusion requirements (pRBC: 3.9 ± 3.3 units vs 14.0 ± 5.8 units; P < .001 and FFP: 1.5 ± 2.2 units vs 5.4 ± 2.8 units; P = .002) were less likely to survive their thoracic aortic insult.

Trauma patients comprised 11 of 51 of the patients included in this study. Complications included multisystem organ failure, type A dissection, and iliac and femoral aneurysms. The complications occurred among patients undergoing TEVAR for trauma. In-hospital mortality was 27.2% and was associated with concurrent injuries, not TEVAR-related complications. Although stroke and paraplegia rates as high as 10% have been reported in the literature, we had 1 patient with an embolic-related event requiring early reintervention.

During follow-up, all patients underwent a CTA for surveillance and there were no endoleaks, graft migration, or device-related complications. Endografts used in our patient population include Talent (Medtronic, Minneapolis, MN) in 4 patients, Zenith (Cook Medical, Bloomington, IN) in 6 patients, Gore TAG (Gore, Flagstaff, AZ) in 4, CTAG (WL Gore, Flagstaff, AZ) in 7 patients, and Relay (Bolton Medical, Sunrise, FL) in 1 patient. Graft choice was based on surgeon preference and graft availability at the time of the intervention.

There are several limitations to our study presented here. This is a retrospective study and our sample size is small. The data set of the cohort presented extends from 2005 to August 2013. Before this time, patients were enrolled in device trials and were not included. Practice patterns have changed over the last years with increasing use of TEVAR and with subsequent technological advances.

### Conclusion

Thoracic aortic emergencies of all types remain challenging. Our experience in a moderate-volume center supports the utilization of TEVAR in the acute setting. Twenty-four-hour pRBC requirements ≥ 4 units, admission MAP < 60 mm Hg, and 24-hour FFP:pRBC ratio < 1:1.5 were independently associated with death. Thoracic endovascular aortic repair offers a minimally invasive treatment approach of descending aortic catastrophes, and open operative approaches can be avoided in most cases. Delayed time to vascular intervention due to other life-saving procedures required in the trauma patient remain a challenge.


References


Discussion

Dr. Mark Langsfeld (Albuquerque, New Mexico). The Arizona group in vascular surgery report their experience with TEVAR in the treatment of a variety of acute descending thoracic aortic emergencies. They used several different commercially available endografts over an 8-year period. Half of the patients in the series were patients sustaining a thoracic aortic injury secondary to blunt trauma. Unfortunately, the numbers of cases for the other acute aortic pathologies is too small to draw any meaningful conclusion. One can conclude from your study, however, that TEVAR is technically feasible for a variety of diseases involving the descending aorta.

Furthermore, there are inherent complications to be expected when placing stiff wires and large endograft devices into the thoracic aorta, especially in very ill patients. At our own academic medical center, our cardiothoracic surgeons refer to vascular surgery almost all cases of descending thoracic aorta pathology, with the hopes of performing a TEVAR and prevent an open thoracotomy.

My first question therefore is, at the University of Arizona, what is your relationship between vascular surgery and cardiothoracic surgery? Do you have any data on the number of open thoracotomies done over this same 8-year time period? My next several questions relate to possible lessons you can teach us based on your experience. First, you had 4 patients who had exploratory laparotomies for concomitant injuries associated with TEVAR. In the trauma setting, can you comment on the general time frame for fixing the thoracic aorta injury in these multiply injured patients?

Next, you observed higher mortality in patients with increased blood transfusions. Can you give us your heparin usage protocol during TEVAR placement, especially in these patients who have potential bleeding abdominal injuries and bleeding head injuries?

I did not see in the manuscript the number of left subclavian arteries you have covered. It sounds like you covered 1 patient. Do you have any recommendations on revascularization of the left subclavian artery after coverage?

Finally, in this very cost-conscious operating room environment era, it is very difficult to have on hand every available graft within every size. In our institution, we pretty much use Gore grafts to handle these TEVARs. You have used approximately 5 different grafts. Can you recommend 1 or 2 grafts that should be able to take care of all these patients with these injuries?

Dr. Angela Echeverria: To answer your first question, as far as our relationship with cardiothoracic surgery is concerned, vascular surgery covers every type of injury that is distal to the take off of the left common carotid. Things that are proximal to the take off of the left common carotid are handled by cardiothoracic surgery. As far as our relationship with cardiothoracic surgery is concerned, there really is not any crossover of the practices whatsoever. In our institution, they take care of everything in the ascending aorta and we take care of everything in the descending aorta. To answer your question about covering the left subclavian, if it is technically feasible to not cover the left subclavian, that is definitely our preference. But if it needs to be covered, revascularization, we usually do a carotid subclavian bypass as far as the revascularization.

As far as the grafts go, I think, in the earlier years, representatives would bring in grafts based on what was needed on a case-by-case basis. At this point in time, what we
have on our shelf is the Gore CTAG graft, and that is my preference as far as performing this procedure is concerned. I think, one, for comfort level. Two, you are only needing to have access through 1 groin to deploy it. And secondarily, the graft can be easily adjusted for proper placement. You can place the graft more distal and you are able to pull it up more proximally to get good placement. You do not necessarily have to use the balloon to secure the location of your graft.

**Dr. Kevin Reavis** (Portland, OR). As an esophageal surgeon, when we get involved in these aortoenteric type situations, it is quite an exciting time in the operating room. I just wanted to know if you could comment on concomitant vascular management when the stents were placed; and you mentioned 2 cases of perforated ulcer and 1 case of aortoesophageal fistula, was the occlusion of vertebral arteries or arterial branches was required to prevent a type 2 endoleak into the enteric access point.

Then secondarily, for those couple of patients that were managed using EVAR, if those were managed long term with lifelong antibiotics, if the patients were counseled to undergo arch reconstruction to basically discontinue antibiotics long term, how was that done?

**Dr. Angela Echeverria**: In the 2 patients that are included here, they were maintained on lifetime antibiotics. The one patient was elderly in age and never made it to the arch reconstruction. I think if they would have been able to survive that operation, then that would have been the route that we would have pursued.

**Dr. Kevin Reavis** (Portland, OR). And were any branches needed to be occluded in the patients during the initial treatment to prevent type 2 endoleak into the esophagus?

**Dr. Angela Echeverria**: Yes. Branch coverage is pretty routine. Otherwise, you do have that type 2 endoleak requiring further interventions.

**Dr. Rifat Latifi** (Tucson, AZ). The main concern among trauma surgeons is the long-term effect of these grafts that we put. What is the latest now on how we should follow-up these patients, 6 months, a year, how long, for 20 years, 50 years? These guys are usually young. How do we follow them? Do we follow them with ultrasound, computed tomography scan, positron emission tomography scan, some new scan that we are going to come up with, magnetic resonance imaging perhaps?

**Dr. Angela Echeverria**: Our protocol at the University of Arizona is, for the first 2 years after thoracic endograft placement, we are following our patients. So they get the initial CTA when they come in for operative planning. They have angiogram in the operating room. They have another CTA at 30 days postoperatively. Then we see the patients back in 6 months and have repeat imaging. At this time, our protocol is imaging every 6 months for the first 2 years, and then annually at that time.

I think that this is still very new technology that we have not really established as far as a specialty a nationwide protocol as far as how these patients are monitored for surveillance.