

Blunt traumatic aortic injury: Initial experience with endovascular repair

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Objectives: Endovascular treatment of traumatic aortic injury (TAI) is an alternative to open repair (OR) in patients with blunt trauma. We report our initial experience after integration of endovascular repair using thoracic devices.

Methods: A retrospective review of a prospectively collected institutional trauma registry was performed. Between September 2005 and November 2008, 71 patients with TAI presented to our institution. Based on imaging, TAIs were classified into grade 1-4 in severity. These included: grade 1, intimal tear; grade 2, intramural hematoma; grade 3, aortic pseudoaneurysm; and grade 4, free rupture. Initial management included resuscitation, blood pressure control, and treatment of associated injuries. After stabilization, all patients were considered for thoracic endovascular aortic repair (TEVAR) using a thoracic device. If contraindicated, candidates underwent OR. Outcome measures were mortality, stroke, paraplegia, intensive care unit (ICU), and hospital stay.

Results: The mean age was 39.8 years, with 50 males. The mean injury severity score (ISS) was 42.6. Nineteen (27%) patients with a mean ISS of 60 died shortly after arrival prior to any vascular intervention. Ten (14%) patients with grade 1 injuries were managed medically. The remaining 42 (59%) patients with grade 2 and 3 injuries underwent repair. Median interval between admission and repair was 4.3 days (range, 0-109 days). Fifteen (21%) patients with a mean ISS of 34.4 underwent OR with no mortality, stroke, or paraplegia. Twenty-seven (38%) patients with a mean ISS of 36.7 underwent TEVAR with no mortality or paraplegia. One TEVAR patient suffered a perioperative stroke. Twenty-two patients had a TAG (W.L. Gore & Associates, Flagstaff, Ariz) device. Four patients had a Talent Thoracic (Medtronic Vascular, Santa Rosa, Calif), and 1 patient had an Excluder (W.L. Gore) device. The left subclavian artery was covered in 13 (48%) patients. Patients who underwent TEVAR were older than those who had OR (47.8 vs 31.1 years, $P < .006$). The aortic diameter proximal to the injury was larger in the TEVAR group (24.4 vs 19.6 mm, $P < .0001$). There was no difference in the mean ICU or hospital length of stay between the two groups. Mortality correlated with the ISS score ($P < .0001$). Median follow-up time was 19.4 months (range, 0-27). Only 56% of the TEVAR patients were fully compliant with their surveillance imaging protocol.

Conclusion: In this initial experience, the results of TEVAR did not differ from OR. Long-term follow-up is required to determine the effectiveness of this treatment strategy. Adherence to follow-up imaging protocols is challenging in this patient population. Next generation devices will make TEVAR applicable to a wider range of patients. (*J Vasc Surg* 2009;49:1403-8.)

Traumatic aortic injury (TAI) is the second most common cause of death after blunt trauma.¹ The majority of injuries result from automobile crashes. The mechanism is thought to be related to differential forces that are created between tissues secondary to deceleration. In the aorta, the greatest strain occurs at the isthmus where a fixed aortic arch connects to a relatively mobile descending thoracic aorta.² A 1958 article by Parmley et al³ reported an 85% pre-hospital mortality in patients with TAI. Traditional open repair (OR) has been associated with high morbidity and mortality. A 20-year meta-analysis published in 1994 reported a mortality and paraplegia rate of 32% and 9.9%, respectively.⁴

Thoracic endovascular aortic repair (TEVAR) offers several advantages compared to OR for management of

TAI. The patients often suffer from multi-organ trauma placing them at higher risk for a procedure that requires open thoracotomy, single-lung ventilation, heparinization, aortic clamping, and often multiple transfusions. Although to date, no specific endograft has been approved by the Food and Drug Administration (FDA) for treatment of TAI, off-label use of commercially available devices is common. Several meta-analyses have documented significantly improved outcomes with TEVAR compared to OR.⁵⁻⁷ We report our initial experience with integration of TEVAR for management of TAI at a major urban trauma center.

METHODS

A retrospective review of a prospectively collected institutional trauma registry was performed. This study was approved by the Committee for the Protection of Human Subjects (CPHS), which acts as the institutional review board. Between September 2005 and November 2008, 71 patients with a diagnosis of TAI presented to our institution. Using imaging, we classified TAIs into four categories based on severity (Fig 1). These included: grade 1, intimal tear; grade 2, intramural hematoma; grade 3, aortic pseu-

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Competition of interest: none.

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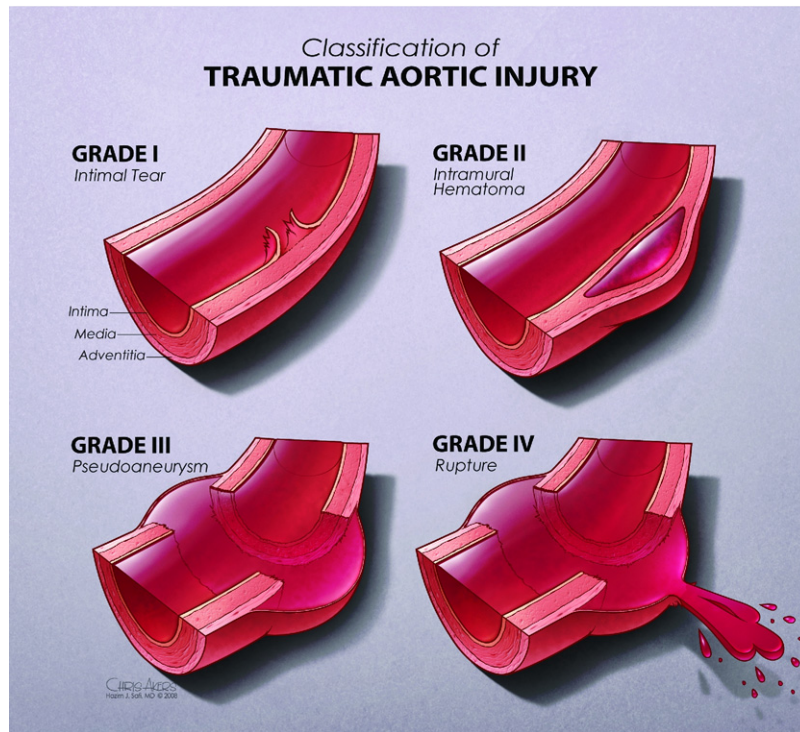


Fig 1. Classification system for traumatic aortic injury.

doaneurysm; and grade 4, free rupture. Initial management included resuscitation, blood pressure control, and treatment of associated injuries. Patients with grade 1 injuries underwent intravascular ultrasound (IVUS) and were managed medically. After stabilization, the remaining patients were considered for endovascular repair using a thoracic device. The suitability of a patient for endovascular repair was based on aortic diameter according to the manufacturer's sizing recommendations for thoracic devices as well as the location of the injury. Patients who were not endovascular candidates underwent OR. Use of abdominal component devices was considered in extreme circumstances when neither a thoracic device nor OR was a suitable option. Main outcome measures were mortality, stroke, paraplegia, intensive care unit (ICU), and hospital stay. Descriptive statistics were computed for all of the groups. Hypothesis tests between the open and endovascular groups were computed by contingency table methods for categorical variables and by unpaired t tests or Wilcoxon rank-sum tests as appropriate for the distributional characteristics of the continuous variables. All computations were performed using SAS software version 9.1.3 (SAS Institute, Inc, Cary, NC). The null hypothesis was rejected at a nominal $P < .05$.

Thoracic endovascular aortic repair. All endovascular procedures were performed under general anesthesia in a hybrid operating room equipped with fixed imaging equipment (Axiom, Siemens Medical, Malvern, Pa). In the first two cases, a cerebrospinal fluid drainage catheter was

inserted based on our institutional protocol for patients undergoing thoracic aneurysm repair. Due to the low risk of paraplegia and our increasing comfort with the procedure, this practice was later abandoned in patients with TAI.

Intraoperatively, the abdomen and bilateral groins were prepped in standard fashion. An arch aortogram was performed through percutaneous femoral access. The location of the injury was confirmed. The cerebrovascular anatomy was evaluated based on the arch angiogram, especially if left subclavian artery coverage was planned. IVUS was used selectively based on the discretion of the attending surgeon. We have found IVUS especially useful in visualizing grade 2 aortic injuries which may be difficult to see on angiogram. Open exposure of the contralateral femoral artery was obtained through a transverse inguinal incision. According to preoperative computed tomography (CT) imaging scans, we generally selected the more suitable (based on diameter, tortuosity, and calcification) iliac artery for device placement. The patient was anticoagulated with weight-based heparin protocol.

The thoracic device(s) (off-label) were selected based on CT image scans according to manufacturer's sizing recommendations. Measurements were made based on two-dimensional thin-cut axial CT scans with intravenous (IV) contrast. An abdominal component device was used in the case of a pediatric patient who could not tolerate a thoracic device or OR. The device(s) was/were delivered and deployed using standard technique without any phar-



Fig 2. Computed tomography (CT) and intravascular ultrasound (IVUS) images of a grade I injury (intimal tear).

macologic adjunct. The subclavian artery was covered as needed to obtain a proximal landing zone or gain better apposition with the lesser curvature of the aortic arch. A policy of selective delayed subclavian artery revascularization was maintained. Postdeployment balloon angioplasty was performed selectively when incomplete apposition of the graft at the proximal landing zone was noted. The delivery devices were removed. The femoral arteriotomy was repaired using polypropylene suture. The heparin was reversed using protamine. The puncture site was managed using a closure device or manual pressure. Postoperatively, patients returned to the trauma surgical ICU. They were subsequently discharged after treatment of other associated injuries.

Open repair. All ORs were performed under general anesthesia using a double lumen endotracheal tube. Neuromonitoring included somatosensory and motor-evoked potential monitoring. Distal aortic perfusion using a Bio-Medicus (Minneapolis, Minn) pump with an inline heat exchanger was used with outflow cannulation from the left inferior pulmonary vein to the distal descending thoracic aorta or left common femoral artery. Systemic heparinization was used at 1 mg/kg. Aortic clamping was performed proximal to the left subclavian artery. The aorta was opened longitudinally and the tear was inspected. Hemostasis was obtained by over-sewing any bleeding intercostal arteries. An appropriately sized woven Dacron tube graft was anastomosed to the proximal aorta with a running 4-0 polypropylene suture. The distal anastomosis was then performed and the graft was flushed just prior to its completion.

Follow-up. The follow-up imaging protocol for the TEVAR patients consisted of a CT scan at 1, 6, and 12 months, postoperatively, and yearly thereafter. The follow-up imaging protocol for OR patients consisted of a yearly chest x-ray. Follow-up information was gathered from office charts and supplemented with telephone interviews when necessary. For the purposes of this publication, these data were also supplemented with the Social Security Death Index.

RESULTS

Among the cohort, the mean age was 39.8 years (range, 14-87, 50 males). The mean injury severity score (ISS) was 42.6 (range, 16-75). The mechanisms of injury included motor vehicle collision (n = 51), motorcycle (n = 7), auto vs pedestrian (n = 5), fall (n = 5), and other (n = 3). Nineteen (27%) patients with a mean ISS of 60 died shortly after arrival prior to any vascular intervention. Ten (14%) patients with grade 1 injuries underwent IVUS and were managed medically. There were no deaths in this group. The remaining 42 (59%) patients with grade 2 and 3 injuries underwent repair. Representative CT scans and IVUS images of patients with grade 1-3 injuries are demonstrated in Figs 2-4. Median interval between admission and repair was 4.3 days (range, 0-109 days). No patient died from aortic rupture while awaiting repair. Fifteen (21%) patients with a mean ISS of 34.4 underwent OR with no mortality, stroke, or paraplegia. Twenty-seven (38%) patients with a mean ISS of 36.7 underwent TEVAR with no mortality or paraplegia. One (3.7%) TEVAR patient suffered a perioperative stroke. A summary of the data is listed in the Table. Twenty-two patients had a TAG device (W.L. Gore & Associates, Flagstaff, Ariz). Four patients had a Talent Thoracic device (Medtronic Vascular, Santa Rosa, Calif), and 1 patient had an Excluder device (W.L. Gore). The technical success rate was 100%. All but 3 patients required a single device. The left subclavian artery was covered in 13 (48%) patients. No patients required an iliac conduit. One patient with an associated brachial plexus injury subsequently underwent a left carotid-subclavian bypass. There were no other reinterventions. The patients who underwent TEVAR were older than those who had OR (47.8 vs 31.1 years, $P < .006$). The aortic diameter proximal to the area of injury was significantly larger in the TEVAR group (24.4 vs 19.6 mm, $P < .0001$, range, 14-36 mm). There was no significant difference in the mean ICU or hospital length of stay between the two groups. Mortality significantly correlated with the ISS score ($P < .0001$). Median follow-up time was 19.4 months (range, 0-27).

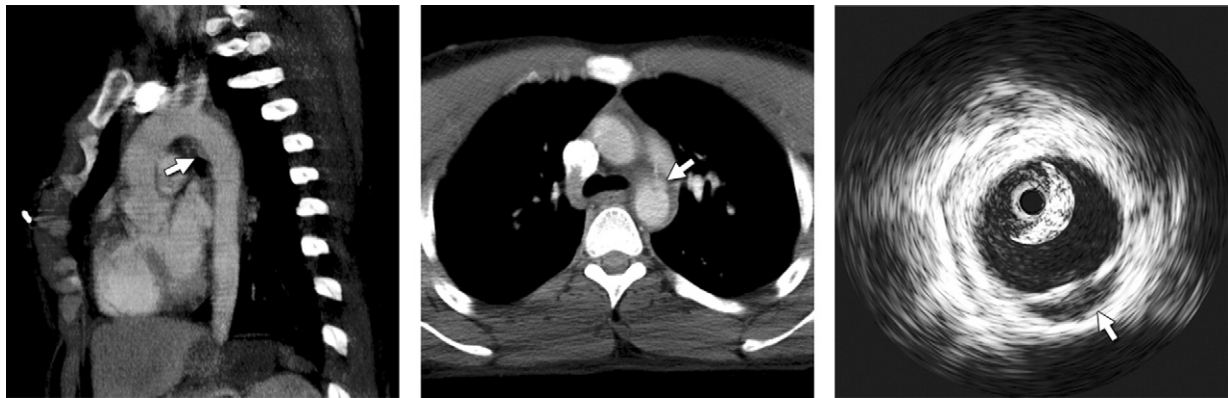


Fig 3. Computed tomography (CT) and intravascular ultrasound (IVUS) images of a grade II injury (intramural hematoma).

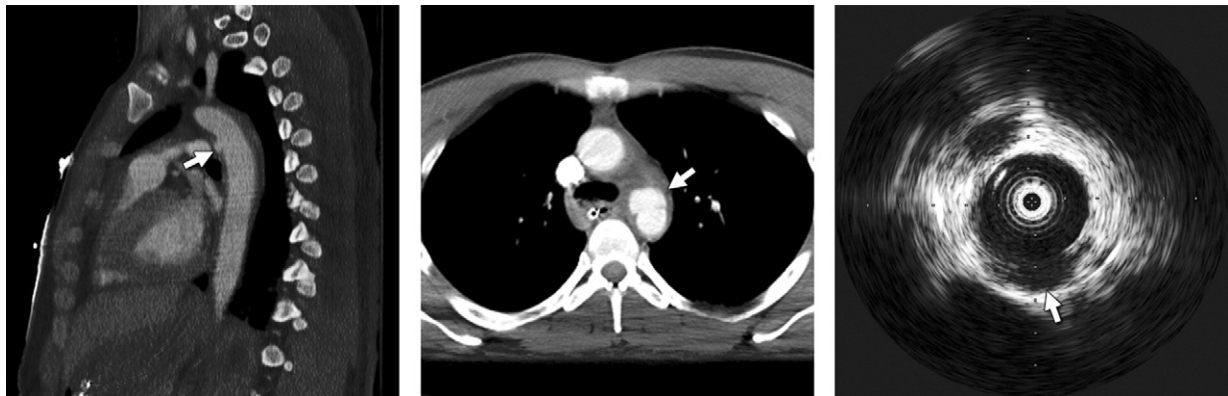


Fig 4. Computed tomography (CT) and intravascular ultrasound (IVUS) images of a grade III injury (pseudoaneurysm).

Only 56% of the TEVAR patients were fully compliant with their surveillance imaging protocol.

DISCUSSION

This study represents a modern series of patients with TAI who presented to a large urban trauma center. First and foremost, the findings confirm that despite modern advances, TAI remains a very lethal condition for the estimated 85% who die in the field and the 27% of the survivors who expire within hours after arrival. A number of other studies have documented the high early mortality of such patients.^{8,9} Undoubtedly, the severity of the associated injuries in this group (ISS = 60) also plays a significant role. In fact, the mean ISS was a significant predictor of mortality. The patients who survive the initial hospitalization, therefore, represent a naturally selected cohort with more stable aortic injuries. Our protocol consisted of initial stabilization, blood pressure control, and treatment of associated injuries followed by delayed repair.⁹⁻¹¹ Under this protocol, no patient died secondary to aortic rupture while awaiting repair.

The initiation of our series (August 2005) corresponds to the FDA approval of the first thoracic endograft (TAG,

W.L. Gore) in the US. Although endovascular repair of TAI using abdominal aortic components has been reported, we have generally limited the endovascular approach at our institution to patients who met sizing criteria for off-label use of thoracic devices.¹²⁻¹⁴ (We made one

Table. Results of open and endovascular repair

	Open repair (OR)	Endovascular repair (ER)	P value
Total number	15	27	
Grade 2	2	3	1.0
Grade 3	13	24	.61
Age (years)	31.1	47.8	< .006
Mean ISS	34.4	36.7	.42
Aortic diameter(mm)	19.6	24.4	< .0001
Repair interval (days)	1.3	6.5	.10
Mortality	0	0	1.0
Stroke	0	1 (3.7%)	1.0
Paraplegia	0	0	1.0
ICU LOS (days)	21.9	15.7	.37
Hospital LOS (days)	33.7	27.3	.48
Follow-up (months)	27	15	.12

ISS, Injury severity score; ICU, intensive care unit; LOS, length of stay.

exception in the case of a pediatric patient with an enlarging pseudoaneurysm who was not a candidate for open repair. In this patient an Excluder [W.L. Gore] iliac limb was used to repair a very small aorta.) The TAG device is available in diameters of 26 to 40 mm to treat aortas between 23 to 37 mm. During the initial phase of our study, patients with aortic diameters less than 23 mm were offered OR. This affect likely accounts for the significant difference in the age of patients and the size of the aortic diameter proximal to the area of injury in the OR vs the TEVAR group. The OR patients were significantly older with larger aortas compared to the TEVAR group. With the approval of the Talent thoracic device (Medtronic) in 2008, which ranges in diameter from 22-46 mm, we were able to offer endovascular repair to a wider range of patients. Overall, 64% (27/42) of our study cohort met criteria for TEVAR with the off-label use of an approved thoracic device. One patient who met sizing criteria for TEVAR underwent OR due to severe aortoiliac occlusive disease extending to the renal arteries. Future generations of devices tailored to repair of traumatic injury will undoubtedly expand the applicability of this technology to a wider range of patients.

A number of recent meta-analyses have documented significantly improved outcomes after TEVAR compared to OR.⁵⁻⁷ A survival benefit for TEVAR patients was also demonstrated in a prospective multicenter study conducted by the American Association for the Surgery of Trauma (AAST).¹⁵ Our study, however, did not show a significant difference in outcomes. This can likely be attributed to a small sample size and the protective use of distal aortic perfusion in the OR group. There was no mortality or paraplegia among the patients who underwent open or endovascular repair. There was one posterior stroke in an 80-year-old woman who underwent TEVAR. In retrospect, this event can be attributed to the severity of the disease in the aortic arch. It is difficult to perform any meaningful statistical analysis with only a single patient reaching an endpoint. Our study demonstrates that the results of TEVAR do not differ from OR. These findings support the use of TEVAR as a first line treatment for TAI.

Management of the left subclavian artery (LSCA) during TEVAR remains a topic of interest. The mechanism of injury often places the tear very close to the distal arch.¹⁶ In our experience, nearly half of the patients (48%) required LSCA coverage in order to obtain an adequate proximal landing zone or arch apposition. We maintained a policy of delayed LSCA transposition or bypass as clinically indicated. We performed a diagnostic arch angiogram prior to TEVAR in order to define the cerebrovascular anatomy. We did not encounter any patients with inadequate collateral vertebral flow. One patient with a documented concomitant left brachial plexus injury underwent a delayed LSCA bypass. This procedure was performed to rule out any arterial ischemia as the cause of the neurologic symptoms. No other patient developed any left arm claudication or ischemic symptoms during the follow-up period. Overall, a policy of delayed selective LSCA revascularization has thus been successful in our experience.

The AAST classifies all TAIs, regardless of severity, as a grade 4 vascular injury.¹⁷ TAIs, however, include a spectrum of defects that range from small intimal tears to complete transections with free rupture. Advances in imaging, including refinements in CT scans and the use of IVUS, have led to the diagnosis of injuries that may have gone unrecognized in the past.¹⁸⁻²¹ The availability of a more detailed classification system facilitates the study of treatment strategies as well as outcomes. This is especially relevant in the case of intimal tears (grade 1) which may potentially be managed non-operatively.²² We certainly recognize the inherent limits of this classification system. First, this is a relatively small group of patients gathered over a short period of time. As a result, meaningful outcome data based on this classification system cannot be provided yet. This will, however, be the subject of future studies as we continue to follow our patients. The second limitation relates to grade 4 injuries. We recognize that the majority of these patients either die in the field or are too unstable on arrival to undergo diagnostic studies. Autopsy studies may at times be the only available information on these patients.

CONCLUSION

Endovascular repair of TAI appears to be a suitable alternative to OR as a first line therapy with favorable results. Long-term follow-up is required to determine the effectiveness of this treatment strategy. Adherence to follow-up imaging protocols is challenging in this patient population. The availability of next generation devices will make endovascular repair applicable to a wider range of patients. The use of a uniform classification system may be helpful in assessment of outcomes, especially in patients with minor injuries.

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AUTHOR CONTRIBUTIONS

Conception and design: AA, CM
Analysis and interpretation: AA, CM
Data collection: AA, KK
Writing the article: AA, AE
Critical revision of the article: SC, HS
Final approval of the article: AA, HS
Statistical analysis: CM
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Overall responsibility: AA

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