Long-term outcomes of thoracic endovascular aortic repair: A single institution's 11-year experience

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BACKGROUND: Thoracic endovascular aortic repair (TEVAR) has largely replaced traditional open aortic repair for anatomically suitable lesions, however, long-term outcomes are unknown.

METHODS: All patients who underwent TEVAR from December 2004 to October 2015 at a single tertiary care institution were included. Demographics, injury pattern, operative details, outcomes, and surveillance were reviewed. Follow-up ranged from 2 to 132 months and was obtained from clinic notes and imaging reports.

RESULTS: A total of 88 patients underwent TEVAR; all suffered from blunt mechanisms, 72.7% were men. Median age, Injury Severity Score, and Trauma and Injury Severity Score was 47 (19.7), 38 (13.5), 0. 8 (0.34). Injuries included 2% grade II, 90% grade III, and 8% grade IV. Overall mortality was 6.8%, TEVAR-related mortality was 0%. Overall in-hospital complication rate was 57%, whereas TEVAR-related complication rate was 9.1%: four typ 1a endoleaks, two typ 2, and two typ 3. Of the typ 1 endoleaks, all required reoperation, whereas all types 2 and 3 endoleaks resolved on subsequent imaging. The left subclavian artery (LSCA) was intentionally covered at index operation in 19 patients (21.6%), and 7 patients (8%) had partial LSCA coverage. The rate of postoperative left upper extremity ischemia was 0%. Left carotid-subclavian bypasses were performed prophylactically in two patients before LSCA coverage at index operation. Eighty-seven percent of endograft access was by performed by open femoral artery exposure and one via retroperitoneal conduit. Percutaneous TEVAR (pTEVAR) was performed more recently in 11.4% of patients with no complications. Heparin was administered intraoperatively in 23 patients with TBI, and 12 patients were not heparinized; no adverse events or outcomes resulted from its use or lack thereof. First, second, and third surveillance imagings occurred at mean intervals of 14 days, 4 months, and 1 year, respectively. Percent of patients followed at 1, 3, and 5 years from operation was 62.1%, 25%, 13.6%, respectively.

CONCLUSION: TEVAR continues to be a feasible treatment modality for blunt traumatic aortic injury with minimal and early device and procedure-specific complications. Follow-up continues to be a significant challenge, and protocols for surveillance imaging are needed. This is the first study to describe access specific outcomes of pTEVAR in trauma patients. Long-term outcomes of TEVAR are still largely unknown; however, these data suggest that it may be at least comparable to open repair. (*J Trauma Acute Care Surg.* 2017;82: 687–693. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic/epidemiologic study, level IV; therapeutic study, level V.

KEY WORDS: Blunt thoracic aortic injury; endovascular repair; stent-graft; outcomes.

The first reported case of thoracic endovascular aortic repair (TEVAR) was reported in 1997,[1] and this technique became the more commonly used treatment for blunt thoracic aortic injury (BTAI) in the following decades. The advent of TEVAR using endovascular stent grafts as definitive therapy has resulted in both improved morbidity and mortality among patients who survive to reach care after BTAI. Although appropriate patient selection remains paramount to success, the successful outcomes of TEVAR have dramatically altered the standard of care for BTAI patients.

The 2008 report of the AAST BTAI study group demonstrated a significant rate of TEVAR-related complications, as 18.4% patients had some form of stent graft specific complication, most notably endoleak in 13.6%.[2] The continued advancement of endovascular technologies since this report, including stents specific for aortic trauma, as well as operator experience, has decreased these adverse events after TEVAR.[3] Paralysis, stroke, and left upper extremity ischemia with left subclavian artery coverage has significantly decreased over time,[4–7] and grading systems to help delineate suitability for endovascular versus open approach, as well as nonoperative management have evolved.[8–10] A few case series from abroad demonstrate good outcomes in a modest size patient population up to 12 years after index operation.[11–14] There is a paucity of data from the United States which is limited either by number of patients[15] or by length of follow-up to 7 years.[9,16] Today, TEVAR continues to replace traditional open aortic repair for anatomically suitable lesions in the United States, however, long-term outcomes are largely unknown. The objective of the study was to assess early and late device-related complications following endovascular repair of blunt thoracic aortic injuries.

PATIENTS AND METHODS

All patients who underwent TEVAR from December 2004 to October 2015 at a single tertiary care institution were included after approval from the institutional review board at the University of Maryland School of Medicine. Trauma registry data was used for age, gender, mechanism of injury, admission physiologic data, Injury Severity Score, Trauma and Injury Severity Score, and hospital length of stay. Admission computed tomography (CT) scans were utilized to categorize the degree of aortic injury based on the Society for Vascular Surgery (SVS) aortic injury scale.[7] Operative details including device access site, method, and complications, endoleaks, status of left subclavian artery, and need for further intervention were obtained from the patient's medical record. In-hospital outcomes including CT scans, access site complications, extremity claudication, paraplegia, stroke, and need for further intervention were obtained from the medical record. Follow-up data including surveillance CT scans, access site complications, extremity claudication, and physical exams ranged from 2 to 132 months, and was obtained from the medical record. We assumed that any patient with a TEVAR-related complication diagnosed at an outside facility would be transferred immediately to our institution, as is the usual practice in our statewide system.

The pTEVAR technique was performed under manufacturer protocol using the 6Fr Perclose ProGlide systems (Abbott Vascular, Inc, Redwood City, CA). The arteriotomy was performed with the microcatheter technique and 2 Proglide systems were placed per the instructions for use, followed by the larger sheath for device access. At the time of access sheath removal, the Proglide systems were secured and the arteriotomy closed.

Data were analyzed using SAS version 9.3 (SAS Institute, Inc., Cary, NC). Categorical variables were computed using Fisher's exact test and continuous variables were compared using Student's t test.

RESULTS

A total of 88 patients underwent TEVAR; all suffered from blunt mechanisms, 72.7% were men. Median age, Injury Severity

Score, Trauma and Injury Severity Score was 47 (19.7), 38 (13.5), 0.8 (0.34). Injuries included 2% grade II, 90% grade III, 8% grade IV. Median ventilator, hospital, and intensive care unit days were 7 (3–17), 16.8 (8.5–24], and 12.3 (5–20). Overall mortality was 6.8% due to intra-abdominal sepsis (1.1%), cardiac arrest (2.3%), grade 5 liver injury (1.1%), and TBI (2.3%). TEVAR-related mortality was 0%. Overall in-hospital complication rate was 57%.

TEVAR-related complication rate was 9.1%: four typ 1a endoleaks, two typ 2, and two typ 3. Of the typ 1 endoleaks, all required reoperation, whereas all types 2 and 3 endoleaks resolved on subsequent imaging. Of the typ 1a endoleaks, one required proximal extension only, one required proximal extension, and an left subclavian-carotid bypass, and 2 required conversion to open repair despite proximal graft extension. No reintervention for endoleak was required after TEVARs performed beyond 2009 (Table 1). Our overall TEVAR reintervention rate was 4.5%.

The LSCA was intentionally covered at index operation in 19 patients, and 7 (8%) patients had partial LSCA coverage. The rate of postoperative left upper extremity ischemia was 0%, and left carotid-subclavian bypasses were performed prophylactically in two patients before LSCA coverage at index operation.

Eighty-seven percent of endograft access was by performed by open femoral artery exposure and one via retroperitoneal conduit due to access vessel diameter and presence of circumferential disease. Percutaneous TEVAR (pTEVAR) was performed more recently in 11.4% of patients with no complications. No access complications occurred with either open or percutaneous methods. Heparin was administered intraoperatively in 23 patients with TBI. 12 patients were not heparinized. No adverse events or outcomes resulted from its use or lack thereof. 66 patients were discharged to rehabilitation centers and 16 patients discharged directly to home.

First, second, and third surveillance imaging occurred at mean intervals of 14 days, 4 months, and 1 year, respectively. The longest imaging surveillance was at 8 years, 11 months, and 7 days from index operation. Percent of patients followed at 1, 3, 5 years from operation was 62.1%, 25%, 13.6%. The median interval from index operation to most recent imaging was 522 (237–1,127) days (range, 4–3,262 days).

DISCUSSION

Over the past decade, TEVAR has emerged as a safe alternative to open repair in BTAI. Early comparisons to open repair in the AAST trial showed improved survival and short-term outcomes, but displayed a high rate (20%) of device-related complications, most notably endoleak in 14.4%.[2] Of those endoleaks, it is not known which type of endoleaks occurred, but 83% required reintervention; nine patients required repeat endovascular treatment, and six patients required an open operation for definitive repair. As part of the morbidity of TEVAR is related to reintervention rates, our data show a trend toward significantly improved outcomes: only 50% of endoleaks required reintervention, resulting in an overall reintervention rate of 4.5%. All endoleaks were diagnosed at the time of operation, or on postoperative CTA within the first 11 days of admission. Mid-term and long-term device-related complications were not observed, and other series with follow-up ranging from 7 to 14 years confirm these to be exceedingly rare,[12] and in many cases, nonexistent.[11,13–15] However, migration, collapse, or stent fracture, also seen very infrequently in follow-up of patients with treated thoracic disease, justify the importance of lifetime surveillance of any TEVAR patient.

The type of endoleaks which develop after TEVAR are also of clinical significance, as some do not require re-intervention, or immediate re-intervention. Endoleaks can be difficult to diagnose, and angiographic interpretation is challenging, particularly when they are small and occur in a very delayed fashion. At times, small endoleaks can be only seen on specific projections. CT scan is less accurate in diagnosing type of endoleak due to the static nature of the images. Delayed CT images can be helpful, but angiography with specific placement of the injection catheter is the criterion standard. Traditional teaching mandated that all endoleaks be fixed immediately at the time of operation. This has progressed over the past decade to only treating endoleaks in which the risk of injury propagation is persistent and high. Triaging endoleaks in a patient with a BTAI is challenging, because the risks of further intervention when multiple competing and injuries are present and spending more time in the OR with more devices in the arch must be weighed against the chances of the endoleak resolving over time.

All type 1a endoleaks required re-intervention, and occurred earlier in the series (Table 1). It is unclear if those were due to stent-graft oversizing, proximal landing zone, device inflexibility in the aortic arch, or a combination of these. The majority of the devices used since 2009 have been approved for use in trauma, and the deployment mechanics and characteristics of these devices make them superior to previous devices intended for treatment of thoracic disease. Currently, three types of endografts are FDA-approved for BTAI (Medtronic Talent/Medtronic Vascular/Santa Rosa CA, Gore TAG/WL Gore and Assoc/Flagstaff AZ, Cook Zenith Alpha/Cook Medical Inc/Bloomington IN), all which offer more conformable grafts, improved deployment systems, as well as the ability to treat aortas as small as 15 mm to 18 mm in diameter through lower profile delivery sheaths.

TABLE 1. Endovascular Reinterventions in BTAI Patients Receiving TEVAR

Patient	Year	Aortic Injury Grade	Admission to Initial OR, h	Endoleak Type	Device Used	Reinterventions
1	2006	3	94	1a	Gore TAG	POD 0: proximal extension graft, conversion to open
2	2008	4	41	1a	Gore TAG	POD 2: proximal extension graft
3	2008	3	180	1a	Gore TAG	POD 5: proximal extension graft, conversion to open
4	2009	3	69	1a	Gore TAG	POD 0: L carotid-SCA bypass, proximal extension graft

L carotid-SCA, left carotid-subclavian artery; POC, postoperative day.

Due to the fairly recent use of TEVAR as a definitive treatment modality for BTAI, it is unknown how the aorta responds to the stent-graft decades after placement. A series from France measured the proximal neck dimensions in 11 patients 10 years after TEVAR, and compared the change in dimension between those less than and greater than 30 years of age. Ten years after treatment, four patients younger than 30 years had a significantly greater proximal diameter increase than seven older patients (4 ± 1.2 mm vs. 1.5 ± 1.7 mm, $p = 0.0037$).[13] Interestingly, the distal neck dimensions did not significantly differ after 10 years between groups (3.3 ± 1.6 mm vs. 2.1 ± 1.6 mm). Despite this small sample population, the rate of aortic growth over a decade seems to be significantly greater in younger patients and occur at the proximal (rather than distal) aorta. Implications of these findings could lead to more aggressive oversizing in younger TEVAR patients, although the diameter increase seen in the series did not lead to any clinical complication such as endoleak or migration. Twenty-five (28%) patients in our series were younger than 30 years, and no patient was under 18 years. The planned percentage of oversizing, particularly in younger patients, must be balanced with the risk of graft collapse. Traditional recommendations for oversizing stent-grafts in the setting of injury are between 10% and 15%, however, we tend to oversize close to 20% in younger patients and in those patients with healthy aortas which can absorb and respond favorably to the larger radial forces. Whether this practice has contributed to our lack of recent and significant endoleaks is unknown.

Left subclavian artery coverage has been a topic of debate with the advent of TEVAR. 29% of our patients had either partial or full LSCA coverage, and only two bypasses were performed at index operation for prevention of left upper extremity ischemia, one of which was performed in a patient with prior LIMA bypass. Results from many other series have demonstrated that coverage of the LSCA artery is safe in most patients, and revascularization can be delayed until the postoperative period and performed only if clinically necessary.[3,5,12,16] Exceptions to this may include patients with left vertebral dominant circulatory systems, cerebrovascular disease or injury, or patients with a LIMA bypass. These TEVARs should be planned on a case-by-case basis keeping in mind competing injuries and overall prognosis. In a series of 82 patients, the LSCA was covered in 39% of patients with only 2 revascularizations required; one at post-op day 1,821 due to progression of chronic atherosclerotic disease in the vertebral artery, and one at day 75 for the concern of upper extremity ischemia.[9] The importance of factors contributing to cerebrovascular perfusion must be acknowledged before coverage of the LSCA, and follow-up is critical for both evaluation of extremity ischemia and progression of atherosclerotic disease. As technology advances in the areas of fenestrated and branched stent-grafts, future devices may allow great vessel perfusion to be uninterrupted despite close proximity to the area of injury.

Early reports of TEVAR acknowledged significant access site complications ranging from 0.5% to 16%.[2,3,14] Percutaneous device access using the Perclose ProGlide system (Abbott Vascular, Inc, Redwood City, CA) was first introduced in 2007 as means of avoiding the morbidity of open groin exposure with its inherent complications most notably infection. Most pTEVAR data, and the only prospective, multicenter, randomized controlled trial of percutaneous access,[17] describe patients with vascular disease whose anatomy differs from most trauma patients. This is the first descriptive series demonstrating no complications in consecutive trauma patients treated with pTEVAR using the 6Fr Proglide system. One previous single-center study demonstrated technical success using a 10Fr Perclose system for pTEVAR in 17 trauma patients representing 71% of all patients treated.[16] This approach seems to be an acceptable alternative due to its less invasive nature, less time to hemostasis, and the potential for more rapid time to ambulation and decreased risk of infection. Keys to successful use include operator training and experience, and patient selection. Less arterial calcification makes trauma patients ideal candidates for this technique, and the usual emergent need for aortic repair in the setting of competing injuries makes a groin cutdown for access and time required for repair even less attractive. The final ten consecutive patients in this series were treated using the pTEVAR technique and had no complications. The majority of our patients had an open femoral approach, and only one minor complication was found incidentally on follow-up imaging—a seroma, which resolved spontaneously. Guidelines from the SVS recommend open femoral exposure for TEVAR access;[7] however, with increasing operator experience and excellent outcomes, pTEVAR may eventually become preferred in patients with favorable femoral anatomy and minimal to no atherosclerotic disease at the arteriotomy site.

Another issue specific to trauma patients is the use of heparin during endovascular procedures. Because many patients have competing injuries, particularly TBI, it is imperative that a risk benefit discussion between the trauma team and interventionalist occurs to best minimize catastrophic complications. Concerns for cerebral embolization from devices in the aortic arch and extremity thromboembolism from large femoral sheaths are the traditional reasons for heparin use in elective settings. SVS guidelines[7] recommend the use of heparin for trauma TEVARs, but at a lower does than in elective cases. Data from our own institution suggests that anticoagulation use is not a predictor of worsening TBI, and those patients who underwent TEVAR more than 24 hours after admission were anticoagulated without incident.[10] In this series, 23 patients with TBI were given heparin without adverse event. The decision to administer heparin was at the discretion of the interventionalist in conjunction with the trauma team. Conversely, 12 patients received no heparin, and no embolic events were noted. In another series of 24 patients, 85% did not receive heparin, and only one suffered a thrombotic event requiring ilieofemoral thrombectomy.[12] It seems that TEVAR without heparin appears to be safe, and use of heparin is also safe in TBI patients, particularly when repair is conducted more than 24 hours after injury.

Paralysis and stroke have been more commonly associated with open repair, however, with the advent of TEVAR, there has been a significant reduction in both. The AAST report from 2008 demonstrated a rate of paralysis in TEVAR patients of 0.8%,[2] whereas a later multi-institutional report showed a rate of paralysis of 0.5%.[3] Stroke rates also declined, with 1.6% of TEVAR patients in the same study suffering CVA,[2] and 1% of patients in the subsequent trial.[3] Several other

studies, including this series, have demonstrated no paralysis or stroke in any TEVAR patient, including during the decade or so of follow-up.[11–14] This diminutive paraplegia complication rate may be due to shorter stent-grafts, the compensatory ability of younger trauma patients, and overall experience with TEVAR. The almost negligible paralysis and stroke rates make this treatment alternative superior to open aortic repair.

Postdischarge surveillance continues to be a recurring problem in our trauma population. Commonly accepted intervals for imaging intervals are at 1, 6, and 12 months from index operation, and yearly thereafter if no abnormalities are seen. Our mean follow-up imaging occurred at 14 days, 4 months, and 1 year. It is possible that many CT scans performed before 1 month were performed in the event that discharge instructions were not adhered to, or due to other indications and the CTA chest as an "add-on" to eliminate multiple scans and their inherent risks. A precipitous decline in follow-up was seen between 1 and 3 years postoperative (63% vs. 25%), with only 13.6% of patients returning at the 5 year mark. Surveillance intervals and choice of surveillance method are still unknowkn. CTA is currently the standard, but angiography, intravascular ultrasound, and radiography are alternative modalities, each with their own risks and benefits. One of the largest limitations of a retrospective review particularly in this patient population is the lack of follow-up data.

Advances in technology will continue to change the landscape of endovascular treatment for trauma. Clinical trials with biodegradable stents are currently ongoing in the areas of cardiac and peripheral interventions,[18,19] and this technology will likely promote expansion and development of materials for stent-grafting in other anatomic locations. Biodegradable stent-grafts would serve useful particularly in the setting of trauma where the temporary nature of the graft would allow exclusion and healing of the injury, while avoiding the potential long-term risks of stenosis, collapse, and/or migration.

CONCLUSION

TEVAR continues to be a feasible treatment modality for BTAI with minimal and early device and procedure-specific complications. Device-related complications have been significantly reduced as a result of improvements in technology and experience. Follow-up continues to be a significant challenge in this population, and protocols for surveillance imaging are needed. Use of percutaneous closure devices for TEVAR in trauma patients is feasible and lacks the complications of open arterial access. Long-term outcomes of TEVAR are still largely unknown, however, these data suggest that it may be at least comparable to open repair.

AUTHORSHIP

M.B. conducted the literature search and designed this study. M.B., W.T., and M.Ha. performed data collection. M.B. and W.T. performed data analysis. M.B., M.Ho., D.S., and T.S. contributed to data interpretation. M.B. and T.S. wrote the manuscript, which M.B., M.Ho., D.S., and T.S. critically revised.

DISCLOSURE

The authors declare no conflicts of interest.

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DISCUSSION

Dr. Demetrios Demetriades (Los Angeles, California): This is an important contribution from the Shock Trauma Center.

The definitive management of blunt thoracic aortic injuries has undergone a revolutionary change over the last decade. Endovascular repair has now largely replaced open surgical repair and has become the new standard of care.

This approach, as we saw, has resulted in a significant reduction of early mortality and complications. However, there are two major unresolved concerns related to this approach: firstly, the high incidence of early device-related complications; and, secondly, the lack of medium- and long-term results after endovascular repair.

This study from the Shock Center provides some useful answers to these questions. Melanie, I have a couple of questions for you.

Firstly, the study included 88 patients with endovascular repair. The incidence of endoleaks was 9.1% which, as you pointed out, is significantly lower than the earlier AAST study in 2008 which showed endoleaks in 14.4%. This is almost certainly due to improved devices and experience. However, the incidence of left subclavian artery occlusion in this study was 21.6%, much higher than the 3.2% reported in the AAST study eight years ago. Some other recent reports show subclavian artery occlusion in up to 58% of the patients. What is the explanation for this? Did it make any difference if the procedure was done by a vascular surgeon or an interventional radiologist?

Although most patients tolerate the subclavian artery occlusion well, some need carotid subclavian bypass, which is not a minor procedure. I, personally, think that any occlusion of the subclavian artery is a significant complication. A young patient may be fine now but 30 years later with arthrosclerosis would it be a problem? Any comments on this issue? Any prospects for the use of branched or fenestrated grafts?

A second comment, only 25% of your patients were followed up at three years, and only 13.6% were followed up at five years after the procedure. I'm not sure if your statement in the manuscript that "long-term outcomes are at least comparable to open repair eleven years after intervention" can be justified. Can you clarify on this? Any thoughts about a national registry which includes these kind of patients?

And, lastly, during the study period how many patients underwent open repair? Under what circumstances would you consider this approach?

Thank you, again. It was really an excellent and useful presentation.

Thank you, Mr. Chairman.

Dr. Matthew J. Wall, Jr. (Houston, Texas): I'd like to congratulate the Maryland group on a large series of patients. The treatment of these injuries has really evolved and we can learn from you.

If I may reiterate one of the other questions, what is your indication for covering the left subclavian and has it evolved? In our practice we have a much higher incidence of having to cover it, perhaps because we believe it's important to place the first fabric-covered stent in an area of the aorta that isn't angulated.

Second, are you using intra-vascular ultrasound (IVUS) routinely for these cases? We use IVUS on every case, as it permits more precise sizing and better determination of the proximal seal zone. We found we have altered our operative plan in about half the cases based on the IVUS findings.

And, lastly, to reiterate Dr. Demetriades' comment, are you doing any fenestrated grafts for the left subclavian? We've had cases that had previous neck procedures and that had a dominant left vertebral artery so that we had to do a fenestrated thoracic aortic graft to preserve the left subclavian artery.

Thank you.

Dr. Patrick Reilly (Philadelphia, Pennsylvania): Melanie, that was a great presentation and it's very impressive data. Just to help put it into perspective can you just tell us how busy at Maryland the group is doing elective thoracic aortic work, and can you just speculate about how that experience has translated into improved outcomes for trauma patients?

Dr. Melanie Hoehn (Baltimore, Maryland): Thank you to Dr. Demetriades for taking the time to review the manuscript and for his insightful comments.

I agree that coverage of the left subclavian is something that shouldn't be taken lightly. And while significant complications are rare, we all know that they do exist.

It's difficult to weigh the potential risks of a carotid subclavian bypass against an early open surgical repair. The vast majority of times it's safe to proceed with the bypass procedure later and that likely outweighs the increased mortality with the original open operation. But, again, the decision shouldn't be taken lightly.

Regarding the low numbers of subclavian coverage in the AAST trial, those studies were quite early in the history of the endovascular procedure. My assumption is that coverage was less understood and less commonly taken on in that time period. But even outside of that there is a significant discrepancy in the literature for the rates of subclavian artery coverage.

The decision to cover the left subclavian artery is not always clear. The surgeon has to weigh the risks of covering the subclavian versus accepting a shorter landing zone. And this can vary from patient to patient and surgeon to surgeon.

The IFU for current device is down to a two centimeter landing zone; but, again, sometimes shorter landing zones are acceptable and effective.

While all of our procedures are performed by vascular surgeons, they are performed by a small subset of the surgeons and no interventional radiologists are contributing to this dataset.

Even with this, there is still significant variation in what is considered adequate for seal, and this is likely contributing to the discrepancy in the literature.

At least two branch devices are on the market now in trials. And fenestrated grafts theoretically can be back tabled modified for all different types of aortic injury.

At the current time we are not involved in the trial, unfortunately. And we are finding that fenestration is rarely necessary. Even without this technology our open rate in recent years is low and our rate of primary repairs since the initiation of TEVAR is zero.

And so we have not found that fenestrating and branch grafts have been mandatory up until this time; although I fully

admit that a branch graft preserving flow to the subclavian definitely will have a role in the future and would be advantageous.

Regarding our follow-up data, the unfortunate truth is that follow-up in this setting is very limited. The patients don't return for their surveillance after they have recovered.

Again, while not scientifically sound, we believe that patients with complications would represent to our institution. The regional center, the regional culture is that once a trauma patient, always a trauma patient. And we get many people with straightforward problems sent back. We also are the referral center for major aortic emergencies in the region. And so for that reason we think we would see these patients as well.

The numbers in all the literature are low regarding follow-up. And, unfortunately, this low follow-up is the best we have and thats what we're using to interpret our long-term outcomes.

A national registry would be ideal. The AAST multi-institutional trial and the Aortic Trauma Foundation are both attempting to fill this gap. And while there are significant deficits in the long-term data regarding TEVAR, I would argue that there is some limitations in the long-term data regarding open repair as well. It's important that we evaluate both of these options in terms of re-intervention rates over the long-term because, as we know, with open repair late complications do occur as well.

As I said before, we have done zero primary open thoracic aortic repairs since our first TEVAR, for better or for worse. In my opinion, very few descending thoracic aortic injuries do not meet anatomic criteria for treatment with a TEVAR.

Access does not appear to be a problem in these patients as it can be with atherosclerotic disease. And my current practice is that patients suitable anatomically are treated primarily with TEVAR and open is reserved for those patients with a failure.

This gets more complicated when you are talking about arch injuries and the distinction between a descending and an arch injury.

Once injury imposes on the left carotid, at that point the benefit of a minimally-invasive operation becomes less apparent and consideration should be given to an open operation.

And regarding Dr. Wall's question, the indication for coverage of the left subclavian, I kind of touched on that, and again there is more surgeon's discretion regarding that decision than may be apparent.

Our practice has evolved even slightly in the opposite direction as Dr. Wall's, in that we are finding that slightly shorter landing zones, again, slightly shorter than the two-centimeter IFU requirement for descending thoracic aortas, are acceptable given the healthy, elastic nature of the proximal aorta.

Again, this has to be weighed between the risks of not sealing versus coverage of the subclavian. I believe we are accepting slightly shorter landing zones and we found that to be effective.

We use IVUS on a handful of cases. Mostly they are used in cases where there is a concern about the aortic diameter. I have not found it to change my plan quite as often as you have but I understand its utility in certain situations.

If there is any question about the landing zone or your dimensions than IVIS is a nice way to get the information that you need.

And, again, we have not performed any fenestrated grafts and we haven't found that to be necessary. We have never had to proceed primary open repair because of an inability to perform a fenestrated procedure. But, we would like to be involved with the branch grafts in the future.

The question from Dr. Reilly, how busy is our thoracic aortic practice. Our vascular group has a very busy thoracic aortic practice. I can't tell you, exactly, but we are probably averaging one to two thoracic aortic cases a week on average. The bulk of these are emergencies as we are an emergency referral center with people being flown in.

The elective vascular aortic practice is present but less dominant. And I do think that this plays a vital role in the surgeon's comfort and ability to take care of difficult proximal lesions.

Thank you.