Coverage of the left subclavian artery during thoracic endovascular aortic repair

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Background: **Thoracic aortic stent grafts require proximal and distal landing zones of adequate length to effectively exclude thoracic aortic lesions. The origins of the left subclavian artery and other aortic arch branch vessels often impose limitations on the proximal landing zone, thereby disallowing endovascular repair of more proximal thoracic lesions.**
Methods: **Between October 2000 and November 2005, 112 patients received stent grafts to treat lesions involving the thoracic aorta. The proximal aspect of the stent graft partially or totally occluded the origin of at least one great vessel in 28 patients (25%). The proximal attachment site was in zone 0 in one patient (3.6%), zone 1 in three patients (10.7%), and zone 2 in 24 patients (85.7%). Patients with proximal implantation in zones 0 or 1 underwent debranching procedures of the supra-aortic vessels before stent graft repair. In one patient who underwent zone 1 deployment, the left subclavian artery was revascularized before stent graft deployment. Among patients who underwent zone 2 deployment with partial or complete occlusion of the left subclavian artery, none underwent prior revascularization. Patients were assessed postoperatively and at follow-up for development of neurologic symptoms as well as symptoms of left upper extremity claudication or ischemia.**
Results: **Mean follow-up was 7.3 months. Among the 24 patients with zone 2 implantation, 10 (42%) had partial left subclavian artery coverage at the time of their primary procedure. A total of 19 patients experienced complete cessation of antegrade flow through the origin of the left subclavian artery without revascularization at the time of the initial endograft repair as a result of a secondary procedure or as a consequence of left subclavian artery thrombosis. Left upper extremity symptoms developed in three (15.8%) patients that did not warrant intervention, and rest pain developed in one (5.3%), which was treated with the deployment of a left subclavian artery stent. Two primary (type IA and type III) endoleaks (7.1%) and one secondary endoleak (type IA) (3.6%) were observed in patients who underwent zone 2 deployment. Three cerebrovascular accidents were observed. Thoracic aortic lesions were successfully excluded in all patients who underwent supra-aortic debranching procedures.**
Conclusion: **Intentional coverage of the origin of the left subclavian artery to obtain an adequate proximal landing zone during endovascular repair of thoracic aortic lesions is well tolerated and may be managed expectantly, with some exceptions. (J Vasc Surg 2007;45:90-5.)**

Thoracic endovascular aortic repair has become a viable option for treating many aortic lesions that occur along this vascular territory. Obtaining proximal and distal landing zones of adequate length is necessary for the successful exclusion of thoracic vascular lesions to protect against rupture. Although the distal landing zone is often limited by the origins of the mesenteric vessels, extra-anatomic bypass has allowed extension of the distal landing zone into the abdominal aortic territory for stent graft exclusion of thoracoabdominal aneurysms.[1] Likewise, within the territory of the aortic arch, the supra-aortic vessels impose limitations on the length of the proximal landing zone.

Many thoracic aortic lesions are close to or involve the left subclavian artery (SCA),[2,3] requiring coverage of the origin of this vessel by the endograft.[4] Recent experience has suggested that expectant management of left SCA coverage is acceptable, with some exceptions.[5-7] Overstenting of the left SCA, with or without revascularization, extends the proximal landing zone and thereby allows endograft exclusion of these more proximal thoracic aortic lesions.

MATERIALS AND METHODS

Between October 2000 and November 2005, 112 patients received stent grafts to treat lesions of the thoracic aorta. Patient names and medical record numbers were obtained from the University of North Carolina Hospitals Thoracic Endovascular Repair Database. Patient demographics, in-patient hospital information, clinic visits, and radiologic data were obtained from electronic and paper records. Institutional Review Board approval was obtained for review of all patient records relevant to this review.

Of the 112 patients in our database, 28 (25%) were identified who had endograft deployment proximal to the distal aspect of the origin of the left SCA (zone 0, 1, or 2). The proximal attachment site was in zone 0 in one patient (3.6%), zone 1 in three patients (10.7%), and zone 2 in 24 patients (85.7%). A retrospective review was performed of patients who had complete or partial coverage of the origin

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of the left SCA, including patients who underwent debranching bypass procedures of the aortic arch vessels before endograft deployment.

Preoperative evaluation involved computer tomography (CT) angiography (CTA) of the chest, abdomen, and pelvis with multiplanar reconstruction. When medically indicated, as in situations of acute or chronic renal insufficiency, magnetic resonance angiography (MRA) was substituted for CTA evaluation. To further evaluate cerebrovascular anatomy, most of the patients in this subgroup underwent preoperative carotid and vertebral artery duplex ultrasonography, thoracic digital subtraction angiography, or MRA, or a combination. In patients who did not undergo supplemental preoperative imaging, the arch vessel anatomy was evaluated intraoperatively before endograft deployment.

Proximal landing zones were classified in relation to the origins of the supra-aortic arch vessels as previously described.[8,9] The location of proximal deployment was defined by the covered portion of the stent graft in cases where the proximal component contained an uncovered or bare section. Aortic debranching bypass procedures were performed in patients who were to undergo zone 0 or zone 1 deployment. Three patients requiring zone 1 deployment underwent revascularization of their left common carotid artery (CCA) with a right-to-left carotid–carotid bypass using a ringed 8-mm polytetrafluoroethylene (PTFE) graft. One of these patients also received a left CCA–left SCA bypass with a 6-mm ringed PTFE graft owing to stenosis of his right vertebral artery and the risk of compromised basilar blood flow with left SCA coverage.

For one patient who required zone 0 deployment to repair a thoracic arch aneurysm, an ascending arch–innominate artery and left CCA bypass was performed. Access was obtained through a median sternotomy, and a 10-mm Dacron bypass graft was anastomosed in an end-to-side fashion using a side-biting clamp on the ascending arch, with the distal anastomosis performed in an end-to-side fashion to the innominate artery. The left CCA was transected and reimplanted on the distal aspect of the bypass graft.

After hospital discharge and recovery from their bypass procedure, patients returned for endograft exclusion of their thoracic aortic lesions.

For endograft repair, anatomic criteria and graft selection were defined by individual instructions for use. Criteria generally included a proximal and distal landing zone of ≥2 cm in length, and endografts were oversized 10% to 20% for elective cases. Commercially available thoracic endograft devices were used when available and are listed in Table I. Owing to a lack of commercially available thoracic stent graft components early in our experience, handmade and abdominal aortic aneurysm (AAA) endograft components were used in four patients.

Follow-up was performed at approximately 1 month, 6 months, 1 year, and annually thereafter. Mean follow-up was 7.3 months. Radiologic evaluation during follow-up consisted of cross-sectional and plain film imaging (four-view radiographs of the chest). Patients were assessed for the development of neurologic and left upper extremity symptoms. Outcomes and endoleak classification were defined as previously described.[10]

Table I. Descending thoracic aorta etiology and endografts utilized

Lesion	*n*	%
Total endovascular repairs in case series	28	100
Elective repairs	19	68
Degenerative/atherosclerotic aneurysms	10	
Fusiform	8	
Saccular	2	
Pseudoaneurysms	9	
Chronic dissection	4	
Chronic transection*	3	
Anastomotic	1	
Penetrating Ulcer	1	
Emergent repairs	9	32
Acute Stanford type B dissection	4	
Traumatic (acute transection)	3	
Infectious (mycotic)	1	
Anastomotic w/fistula to bronchus	1	
Endografts used	28	100
Talent Thoracic†	9	32
Gore TAG	8	29
Zenith TX2 TAA§	4	14
AAA endograft components**	4	14
Bolton Relay††	2	7
Hand-made‡‡	1	4

AAA, Abdominal aortic aneurysm; *TAA,* thoracic aortic aneurysm.
‡W. L. Gore & Associates Inc, Flagstaff, Ariz.
*All 3 patients reported a history of blunt chest trauma.
†Medtronic AVE, Santa Rosa, Calif.
§Cook Inc, Bloomington, Ind.
**One patient received a modified main body Zenith AAA endovascular graft (Cook Inc) and two main body extensions. Two patients received AAA extender components of the Gore Excluder Bifurcated Endoprosthesis (W. L Gore & Associates Inc).
††Bolton Medical, Sunrise, Fla.
‡‡Constructed from Gianturco Z-stents and woven Dacron graft.

Primary technical, primary clinical, and assisted primary clinical success was 100%, 89%, and 96%, respectively. Of the 28 patients, 19 (68%) were treated electively and 9 (32%) were treated emergently. The etiology of electively and emergently treated thoracic lesions is listed in Table I. The average age of the patients was 63.2 years (range, 18 to 84); 19 (68%) were men and nine (32%) were women. Nineteen patients (68%) had three or more chronic comorbidities as outlined in our previous report.[11] Four patients had undergone previous open AAA repair, and all underwent cerebrospinal fluid drainage at the time of endograft deployment. All patients were classified as having am American Society of Anesthesiologists (ASA) physical status of ≥3.

RESULTS

The overall 30-day mortality was 11% (3/28). The 30-day mortality for elective and emergent subgroups was 5% (1/19) and 22% (2/9), respectively (χ^2 analysis; P = NS). Both deaths in the emergently treated subgroup occurred n

Table II. Complications

	n	%
Total endovascular repairs in case series	28	100
Elective repairs	19	68
30-day mortality	1	5
Complications		
MSOF	1	
Respiratory failure	1	
Cardiac	0	
Renal (ARF/ARI)[b]	0	
Endoleaks	2	
Emergent repairs	9	32
30-day Mortality	2	22
Complications		
MSOF[a]	2	
Respiratory failure	6	
Cardiac	0	
Renal (ARF/ARI)[b]	2	
Endoleaks	1	
Complete left SCA coverage*	18	64
Debranching procedure	4	
Left subclavian artery revascularization	1	
Cerebrovascular accident	2	
Left upper extremity symptoms	3	
Partial left SCA coverage*	10	36
Cerebrovascular accident	1	
Left upper extremity symptoms	0	
Conversion to total left SCA coverage/occlusion	2	
Left SCA vessel thrombosis	1	
Coverage following a secondary procedure	1	
Left upper extremity symptoms	1	

MSOF, multisystem organ failure; *ARF,* acute renal failure; *ARI*, acute renal insufficiency; *SCA,* subclavian artery.

*Complete or partial coverage of the left subclavian artery at the time of primary endograft deployment.

patients who developed multisystem organ failure (MSOF) as a complication of insults sustained from acute type B dissections. The electively treated patient who died had undergone aortomesenteric bypass grafting the day before thoracic endografting to extend his distal landing zone. He died 6 days after endograft deployment from MSOF. Two additional patients died during follow-up at approximately 5 and 18 months from complications of pre-existing end-stage renal disease and congestive heart failure, respectively. No deaths or complications were due to aneurysm rupture.

Common complications after elective and emergent endograft repair are summarized in Table II. There were no cases of paraplegia. No major complications developed in the four patients who underwent debranching bypass procedures before endograft deployment in zones 0 or 1, and none were found to have endoleaks during follow-up. One patient who underwent a right-to-left CCA bypasses without left SCA revascularization reported mild left hand claudication and dizziness with rotation of his head to the far right, which resolved with return to midline. The patient denied neurologic symptoms with increased activity of his left upper extremity, and carotid and vertebral duplex ultrasound imaging demonstrated patency of the bypass graft, retrograde flow in the left vertebral artery, and no change in flow patterns when the patient turned his head to the right to reproduce his symptoms.

Of the 24 patients who underwent deployment in zone 2, 14 (58.3%) had complete coverage of the origin of the left SCA at the time of primary endograft repair. None of these patients underwent left SCA revascularization before endograft repair. One primary endoleak was detected (type III), which was successfully treated with the deployment of an additional stent graft component. One patient who received a thoracic endograft to treat a contained ruptured mycotic aneurysm reported left upper extremity rest pain. A preprocedural thoracic arteriogram had demonstrated a transverse arch origin of the left vertebral artery. The patient underwent left SCA stent placement, resulting in resolution of symptoms.

Of the 10 zone 2 patients (35.7%) who underwent partial coverage of the origin of the left SCA, one patient was found to have thrombosis of the proximal 2 cm of the left SCA, with distal reconstitution on follow-up CT scan at 14 months, and remained asymptomatic. Two type IA endoleaks were observed in two patients and occurred at 7 days and 6 months after endograft deployment, respectively. One patient underwent endovascular balloon remodeling, resulting in total occlusion of the origin of the left SCA and the development of numbness and tingling in her left upper extremity with activity, but her symptoms were not severe enough to warrant an intervention. The second patient underwent deployment of an additional stent graft component and attempted coil embolization; however, these did not resolve the endoleak.

Three cerebrovascular accidents (CVAs) (10.7%) were observed in our subgroup of 28 patients, an incidence that appeared higher than the five (4.5%) that occurred in our overall series of 112 patients. When the incidence of CVAs in patients who underwent zone 0, 1, or 2 deployment was compared with those who underwent deployment in zone 3 or 4 (2/82, 2.4%), the difference approached significance (χ^2 analysis; $P = .06$).

Two CVAs occurred in patients whose left SCA had been completely covered. One of the CVAs was discovered the day after endograft repair and was assessed from CT imaging of the brain to be embolic. The second patient's CVA occurred secondary to hypotension during an intraoperative cardiac arrest that occurred immediately after emergent endograft deployment to treat an acute type B dissection involving malperfusion of the mesenteric vessels and lower extremities. The patient's CVA was demonstrated to have occurred in a left frontoparietal watershed distribution, and MRA demonstrated a patent basilar system supplied by the right vertebral artery. The patient who experienced a CVA after partial coverage was assessed to be embolic by CT imaging.

Overall, 19 (68%) of the 28 patients experienced a complete cessation of antegrade flow through the origin of their left SCA without revascularization either at the time of endograft deployment (n = 14), after a secondary procedure (n = 2), or due to vessel thrombosis (n = 1). Left upper extremity symptoms developed in three patients

(15.8%) that did not warrant intervention, and one patient (5.3%) required a secondary procedure to treat rest pain.

DISCUSSION

Of the 28 patients who underwent zone 0, 1, or 2 deployment, 19 experienced complete cessation of antegrade flow through the left SCA. Four (21%) of these patients experienced left upper extremity symptoms, but only one (5%) required an intervention. As described, this patient was treated emergently for a ruptured mycotic aneurysm and was known to have an aortic arch origin of the left vertebral artery. Our 21% incidence of left upper extremity symptoms is consistent with previous observations after left SCA coverage without revascularization, in which approximately 63% to 100% of patients remain asymptomatic at follow-up and most do not have symptoms severe enough to require an intervention.[5-7,12] In earlier reports, the left SCA was routinely revascularized before endograft coverage owing to concern about the potential for left upper extremity ischemia and vertebrobasilar insufficiency,[13] but these more recent results suggest prophylactic revascularization is not necessary.

When symptoms occur after left SCA coverage they may include neurologic signs consistent with vertebrobasilar insufficiency as well as left upper extremity hypoperfusion, such as claudication, rest pain, or ischemia. To decrease the likelihood of these complications, patients should undergo preprocedural carotid and vertebral duplex ultrasound imaging, digital subtraction angiography, CTA, or MRA to evaluate for the patency, size, and location of the contralateral vertebral artery as well as to rule out an aortic arch origin of the left vertebral artery. The carotid arteries should also undergo concomitant evaluation to rule out stenosis. Cerebral angiography or MRA has a role in determining the presence of an intact circle of Willis to exclude a dominant left vertebral artery system and to ensure sufficient collateral blood flow.

Contraindications to left SCA coverage without preprocedural left SCA revascularization include an aberrant left vertebral artery, a dominant left vertebral artery blood supply to the basilar system, previous coronary artery bypass procedure with a patent left internal mammary artery, and a functioning arteriovenous fistula in the left upper extremity. For patients who develop left upper extremity symptoms, later revascularization can be performed depending upon the severity of these symptoms and should be considered in situations of left-handed professionals, younger patients, or when these symptoms are lifestyle limiting; otherwise, expectant management is appropriate.

Partial left SCA coverage was well tolerated owing to persistent antegrade flow through the ostium of the vessel but may have placed patients at risk for the development of type IA endoleaks, as was observed in two patients. This is due to the difficulty of obtaining adequate proximal stent graft apposition to the distal arch curvature in the territory near the left SCA. Partial occlusion may also lead to vessel thrombosis, as was observed in one patient in our series. Because of the risks of eventual occlusion of the left SCA and some uncertainty about how the endograft will conform to the curvature of the arch at the time of deployment, preoperative evaluation should be identical for patients in whom some degree of impediment upon the ostium of the left SCA is anticipated.

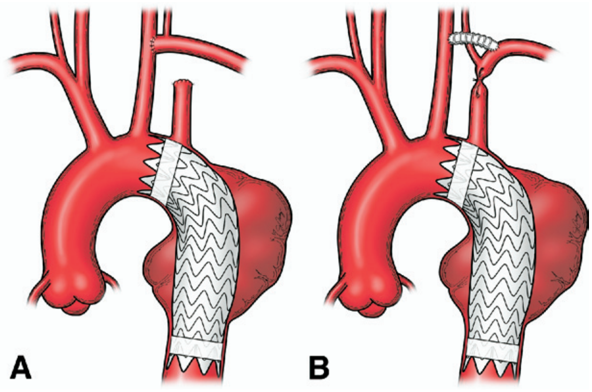

Fig. Options for left subclavian artery revascularization. **A,** Transposition of the left subclavian artery to the left common carotid artery. **B,** Bypass of the left common carotid artery to the left subclavian artery.

Left SCA revascularization options before and after endograft deployment include CCA–SCA bypass or transposition (Fig, *A* and *B*).[14] Although both of these procedures are technically straightforward, they do have associated morbidity.[15,16] It is unknown which procedure is more advantageous when used concomitantly with thoracic endograft repair, although previous studies have suggested an advantage in terms of long-term patency with left SCA–left CCA transposition in the setting of arterial occlusive disease.[15,17] Additional techniques described to revascularize the left SCA include endovascular transluminal graft fenestration,[18] and transluminal placement of endovascular stents at the ostia of the supra-aortic vessels to re-establish or ensure blood flow.[19,20]

CVAs in this subgroup of 28 patients appeared to occur at a higher incidence compared with our overall series of patients, although this did not reach statistical significance ($P = .06$). Catheter, wire, and sheath manipulations in the aortic arch during stent graft deployment may be a source of emboli. Larger studies may confirm if patients with proximal aortic lesions are at greater risk for this complication with endograft repair. No cases of paraplegia occurred within this subgroup, nor have there been in our overall series of 112 patients. Given that the vertebral artery supplies the superior portion of the anterior spinal artery, coverage of the left SCA may disrupt an important collateral source of spinal perfusion in patients with prior AAA repair as well as in those who will undergo extensive thoracic aortic coverage.

Our study is limited by its retrospective design, diversity of thoracic aortic pathology, combination of elective and emergent repairs, small numbers, and limited follow-up. Preoperative radiographic evaluation of elective patients allowed for identification of patients at risk for left upper extremity symptoms as well as those at risk for vertebrobasilar insufficiency or stroke based upon cerebrovascular anatomy.

CONCLUSION

Coverage of the left SCA origin usually does not lead to left upper extremity ischemic symptoms and can be managed expectantly. Although manipulation of guidewires and deployment devices within the arch may place patients at risk for embolic events, left SCA coverage appears to be well tolerated in individuals with collateral perfusion to the basilar system. Partial left SCA coverage may place the patient at risk for the development of a type IA endoleak.

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AUTHOR CONTRIBUTIONS

Conception and design: PR, MF
Analysis and interpretation: PR, MF, RM, WM, JF, BK
Data collection: PR, JF
Writing the article: PR
Critical revision of the article: PR, MF, RM, WM, JF, BK
Final approval of the article: PR, MF, RM, WM, JF, BK
Statistical analysis: PR, MF
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Overall responsibility: MF

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DISCUSSION

Dr Joseph Coselli (Houston, Tex). The authors should be congratulated on a very fine presentation. This is going to be a very important contribution providing additional baseline data regarding left subclavian artery occlusion during thoracic stent grafting with exclusion of thoracic aortic pathology. The mortality and stroke rates, however, were rather notable, both being at about 11%. This is generally higher than what we would like to see in a minimally invasive procedure although, admittedly, in your series nine of your patients, 32%, had undergone emergency repairs.

We, in our work, have an expanding group of these debranching procedures where the total arch is replaced using zone 1 and would concur with your findings that, as of yet, although complications certainly occur, strokes really have not been a significant problem. As of yet, neurological complications, in our experience, have not occurred. We, however, have carried out all of our procedures at the same operative setting, with both the debranching and the endovascular exclusion carried out under the same anesthetic. Intentional coverage of the left subclavian artery has been demonstrated to be reasonable and safe in this setting. But, do you believe that there is a difference in the incidence of endoleaks, particularly type 2, when the left subclavian artery arises off an aneurysmal portion of the aorta versus arising as a branch from a normal aortic segment where the technique is really employed to extend and enhance the proximal landing zone?

In your manuscript, which you kindly provided in advance, you don't address the other two strokes, and I think the manuscript would benefit from additional information regarding the distribution of the embolic strokes. For example, were they occurring in the distribution of the left vertebral artery?

The manuscript also does not address the issue of paraplegia. The vertebral artery branch of the left subclavian artery is, of course, an inflow source to the anterior spinal artery. Could you comment further on paraplegia as an entity, both for this particular subset of patients as well as your broader experience regarding coverage of the descending thoracic aorta?

I would appreciate your thoughts on the routine use of CSF drainage. You mention that you use it in patients who either had concomitant or prior abdominal aortic aneurysm replacement. You have an overall experience I think which would be valuable to comment on the routine CSF drainage.

Would you please comment on the need for the immediate availability of cardiopulmonary bypass when using zone one?

Emergency cases seem to pose several problems that might make ischemic complications more likely. Understandably, they may not undergo sufficient evaluation of cerebral circulation before the procedure and may present with associated shock and coexisting injuries making their neurological status difficult to assess. Similarly, their early postoperative course may make neurological assessment challenging. Finally, ongoing global hypoperfusion, as you had in one of your own patients due to organ failure and other injuries, may exacerbate ischemic complications. Given these concerns, should the left subclavian artery be routinely revascularized during stent graft placement where you had these conflicting issues?

Finally, do you have a concern about the long-term durability of an unsupported ascending aorta for a proximal landing site, not only in patients with significant connective tissue issues, such as Marfan syndrome or Ehler-Danlos syndrome, but also in patients with reduced aortic wall strength and integrity of lesser severity such as those with bicuspid aortic valves, etc? You have recommended that the patients undergo preprocedural studies to identify those at risk for vertebrobasilar insufficiency, yet the information obtained, at least in your manuscript, was not actually used to modify the procedures carried out. Would you comment, consequently, on how strongly you recommend this process?

Dr Paul J. Riesenman. Thank you, Dr Coselli. To address some of those issues, with respect to our three strokes, as I said in the presentation, one patient did sustain his CVA as a consequence of his intraoperative cardiac arrest, and it was a watershed pattern seen on subsequent CT scan. An additional patient had a similar pattern and appeared to be possibly from a hypotensive episode. The other patient actually did not have any radiographic signs or evidence of stroke but he did have clinical symptoms of it. All those patients underwent MR evaluation, which showed that the stroke was not a consequence of a loss of blood flow to the vertebrobasilar territory, so these were not strokes within that territory. If they were, we would conclude they were a consequence of coverage of the left subclavian and cessation of blood flow to the left vertebral.

With respect to our paraplegia, we have not seen—yes, the left vertebral can contribute to flow through the anterior spinal artery— but we have not had any evidence of paraplegia in our overall group, nor have we in this subgroup whatsoever.

With respect to routine CSF drainage, we typically only use that in patients who have undergone previous abdominal aortic aneurysm repair but not necessarily in patients who do not have pathology below their diaphragm.

There were several other questions. I can't remember them all that you proposed to me.

Dr Mark Farber. Let me add to that. Dr Riesenman is a third-year resident in our program and he has done a terrific job, but to answer some of the issues that Dr Coselli brings up in terms of the routine left subclavian artery revascularization, we do evaluate our patients either with CTA or MRA of the circle of the Willis and the entire system and you can do that in most emergent cases except the patients who come in with ruptured aneurysms. The transection patients and dissection patients, they usually get that type of evaluation. We are looking for a few things. We want to make sure that they do not have a left vertebral that comes off the arch. The one patient that did have some rest pain had a left vertebral that came off the arch, and that is what provides the outflow to the left arm and prevents most of these patients from becoming symptomatic.

The second thing that we are looking at is, obviously, if they had a coronary bypass graft, do you have a bypass graft based off the left subclavian system as inflow? We do not want to create a coronary problem for them.

In the two other situations to come up, about 0.4% of the patients will have a left vertebral that does not form up with the right vertebral to give you a true basilar, complete system, and they will suffer a posterior stroke if you cover the left subclavian or what we call dominant left vertebral artery situations.

Lastly, Peter Linn presented some anatomic variants where the right vertebral will actually come off distal to the left subclavian artery and so, technically, you could cover both vertebrals up if you cover the left subclavian and then have a vertebral that is aberrant and comes off distally, so each of those things have to be looked at. You have to know that those are low incidence of anomalies that exist and that you are going to address those.

Lastly, routine use of CSF drainage. While all of us have these anecdotal issues where we put a CSF catheter in and got resolution of spinal cord paraplegia, there is no data that shows it has been of benefit in any level 1 instance. There are several of us that have gotten together and have a proposal to get together to do this as a nationwide evaluation of CSF drainage for thoracic endograft to see if there is a benefit, what the risks are to it, and see if we can improve it.

Lastly, Dr Coselli mentioned the stroke risk being higher than what we'd like. That is true of all thoracic endograft procedures. It is higher than our paraplegia risks in most studies. Ours was 11%, but you are working further around in the arch and I would say that raises it from the 6% to 8% that we see for a zone 3 or zone 4 deployment and raises it somewhat. You have to be very careful with your technique and what you are doing.