Use of carotid–subclavian arterial bypass and thoracic endovascular aortic repair to minimize cerebral ischemia in total aortic arch reconstruction

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Objective: Total aortic arch replacement typically requires hypothermic circulatory arrest, carrying risks of cerebral ischemia. We recently introduced left carotid–subclavian bypass before total aortic arch replacement with thoracic stent grafting to achieve hybrid arch reconstruction with short periods of selective antegrade cerebral perfusion.

Methods: From 2004 to 2009, 332 patients underwent ascending aorta or arch replacements. Of these, 37 underwent total aortic arch replacement. In 2008, we began performing left carotid–subclavian bypass before subtotal arch replacement, with side-graft anastomoses to innominate and left carotid arteries. Patients then underwent aortic graft stent deployment to complete arch reconstruction. Twenty-eight patients underwent conventional arch replacement (group I); 9 underwent hybrid arch replacement (group II).

Results: Selective antegrade cerebral perfusion time in group I was 33.3 ± 13.7 minutes versus 18.9 ± 9.2 minutes in group II ($P = .007$). Among group I patients, 82% required hypothermic circulatory arrest (vs 0% in group II, $P < .001$). Mean cardiopulmonary bypass and aortic crossclamp times were longer in group I than group II ($P < .05$). Incidence of neurologic complications was 14% in group I (4/28) versus 0% (0/9) in group II, although this finding did not reach statistical significance ($P = .55$).

Conclusions: Left carotid–subclavian bypass before arch replacement with staged thoracic stent grafting to achieve hybrid arch reconstruction was associated with decreased selective antegrade cerebral perfusion, cardiopulmonary bypass, and aortic crossclamp times and eliminated hypothermic circulatory arrest. This technique may minimize neurologic complications associated with arch replacement and provide a viable hybrid approach to patients with arch aneurysms and dissections. (J Thorac Cardiovasc Surg 2010;139:717-22)

Conventional approaches to total aortic arch replacement (TAAR) typically require either a period of hypothermic circulatory arrest (HCA), the use of selective antegrade cerebral perfusion (SACP), or both, carrying risks of cerebral and spinal cord ischemia. In addition, extensive arch and thoracic aneurysms generally involve complex, staged operations that carry substantial perioperative mortality risk, as well as significant risks of aneurysmal rupture between the staged operative interventions.^{1,2} As a result, hybrid arch repairs have been introduced that use open subtotal aortic arch replacements combined with concomitant or staged thoracic endovascular aneurysm repair (TEVAR) in attempts to simplify the strategy for completion of the TAAR.³⁻⁶

Our goals in designing a hybrid arch repair included the following: (1) elimination of the use of HCA during the open repair and of a second, complex open surgical procedure; (2) compatibility with root procedures that are frequently required in this patient group, such as “bioroots” or valve-sparing root procedures; (3) simplification of the TEVAR approach to make it feasible and easily reproducible; and (4) elimination of the left subclavian–graft anastomosis, because it is most difficult to visualize adequately through a median sternotomy. To this end, we recently introduced the use of left carotid–subclavian arterial bypass (CSB) before TAAR with staged thoracic stent grafting to achieve a hybrid total arch reconstruction with relatively short periods of SACP and without the need for HCA or a second open surgical procedure. The aortic graft serves as a relatively long proximal landing zone that makes the TEVAR procedure relatively straightforward and reproducible. For the purposes of this study, we compared our institutional experiences with conventional and hybrid TAAR.

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MATERIALS AND METHODS

Patient Selection

A retrospective review of all aortic procedures performed at Columbia Presbyterian Medical Center, New York, from January 1, 2004, to May 1,

Abbreviations and Acronyms

CPB	= cardiopulmonary bypass
CSB	= carotid–subclavian arterial bypass
HCA	= hypothermic circulatory arrest
SACP	= selective antegrade cerebral perfusion
TAAR	= total aortic arch replacement
TEVAR	= thoracic endovascular aneurysm repair

2009, was conducted. A total of 332 patients underwent aortic procedures during this period at our institution. Of these, 37 patients underwent TAAR, and these patients were the focus of our study. The indication for TAAR was an arch aneurysm with or without type A aortic dissection. The study was approved by the local institutional review board, and requirements for informed consent were waived.

Of the 37 patients who had undergone TAAR, 28 patients had undergone conventional repair with right axillary artery cannulation and use of HCA with periods of SACP. These patients comprised group I. Starting in January 2008, we began using a hybrid approach for TAAR without the use of HCA. This technique, which is described in detail in the Operative Technique section, involves the use of right axillary cannulation, a subtotal aortic arch replacement with side grafts to the innominate and left carotid arteries, left CSB, and either concomitant or staged thoracic aortic stent grafting to complete the TAAR. The 9 consecutive patients who underwent hybrid repair comprise group II.

Operative Technique

All operations were done through median sternotomy. Cardiopulmonary bypass (CPB) was established by cannulation of the right axillary artery and right atrium, as previously described.⁷ Briefly, the right axillary cannulation technique involved sewing an 8-mm Dacron polyester fabric graft end-to-side to the axillary artery with 6-0 monofilament suture. A 24F end-hole wire-wrapped aortic cannula was then passed through the graft and secured in place with silk ties. Systemic hypothermia with a target temperature of 28 °C was used for group II patients, for whom SACP was used without the use of HCA. Group I patients were cooled to a target temperature of 18 °C to meet the requirements for HCA and periods of SACP. Antegrade and retrograde blood cardioplegic doses were given initially, with repeat cardioplegic doses typically given at 20-minute intervals in a retrograde fashion.

Group I patients underwent conventional TAAR. A Hemashield aortic graft with separate side arms for the 3 arch vessels (Maquet Cardiovascular, San Jose, Calif) was used. Anastomoses between the graft and the distal aorta and between the graft and the left subclavian and left carotid arteries were performed in sequence under HCA. The innominate anastomosis was typically performed under SACP whenever technically feasible. CPB was then resumed with a clamp on the graft proximal to the head vessels. The proximal aorta–graft anastomosis and any concomitant proximal procedures (eg, valve-sparing aortic root reconstructions, root replacement) were then completed during rewarming.

Group II patients underwent a hybrid arch repair. These patients first underwent a left CSB (in the same operating room session) through a standard left supraclavicular incision. The right axillary artery graft was then sewn and the graft cannulated. We have designed a custom-made Dacron polyester fabric aortic graft (Terumo Cardiovascular Systems, Ann Arbor, Mich), although such a construct can be fashioned with generic grafts on the back table (Figure 1). These grafts ranged from 28 to 32 mm in size. Before initiation of CPB, the left carotid artery was clamped and divided. During this period, carotid flow was temporarily maintained by the left CSB flow. We performed the graft to left carotid anastomosis and subsequently clamped this sidearm of the graft. We then initiated CPB and crossclamped the aorta.

FIGURE 1. Photograph depicting example of custom-made Dacron polyester fabric graft (Terumo Cardiovascular Systems, Ann Arbor, Mich) currently being used for hybrid total arch reconstruction. Labels denote graft orientations of proximal and distal ends, as well as side arms for the innominate and left carotid anastomoses. There is additional 9-mm side arm for access with concomitant thoracic endovascular aneurysm repair. This is performed in an antegrade fashion into the distal end of the graft to complete the total arch reconstruction. If staged thoracic endovascular aneurysm repair is performed endovascularly, radiopaque markers aid in this transfemoral approach, marking the most proximal margin of proximal landing zone.

After the target temperature of 28 °C was reached, we transitioned to SACP by clamping the innominate artery to perform the anastomoses of the distal graft to the aorta and the graft to the innominate artery. We subsequently clamped the graft proximally and reinstituted full CPB. During the rewarming phase, we performed our proximal anastomosis and completed any root or valve-sparing procedures. We have found that visualization for concomitant root replacement is made technically easier by transecting our graft in 2 pieces and then performing a graft–graft anastomosis. In these group II patients, the left subclavian artery was divided with an endovascular stapler before closure of the sternotomy to avoid competitive flow to the left subclavian artery through the left CSB. Figure 2 is an illustration of the completed open subtotal aortic arch replacement with side grafts to the cerebral vessels used in our group II patients.

The hybrid arch repair was completed with either concomitant ($n = 2$) or staged ($n = 7$) TEVAR with thoracic stent graft deployment directly into our aortic graft, which was used as our proximal landing zone. A proximal landing zone at least 2 cm in length was created with the custom aortic graft, although the landing zone was typically much longer than 2 cm. Approximately 10% oversizing was used with the stent graft relative to the aortic graft size. That is, 28-mm aortic grafts were treated with a size 31-mm GORE-TAG stent device (W. L. Gore & Associates, Inc, Flagstaff, Ariz), 30-mm aortic grafts with a size 34-mm GORE-TAG device, and 32-mm aortic grafts with a 37-mm GORE-TAG device.

A 9-mm sidearm (Figure 1) allowed antegrade deployment of the stent graft intraoperatively as part of concomitant TEVAR. In these cases, we elected to deploy the GORE-TAG stent without the sheath, which allowed us to use the 9-mm sidearm. The sidearm was placed adjacent to grafts for the cerebral vessels to avoid kinking of the graft during placement of the stent. If the sheath were to be used during antegrade deployment, a larger sidearm graft (at least 10 mm) would be required, and the graft could be placed more proximally on the aortic graft to permit easier handling of the sheath. The sidearm was ligated after deployment of the stent. In staged

FIGURE 2. Illustration depicting completed open repair in the group II patients. Approach involves starting with left carotid subclavian bypass. Graft–left carotid anastomosis is performed off cardiopulmonary bypass after clamping of left carotid artery. During this time, blood supply is temporarily provided through left subclavian–left carotid flow. Subsequently, selective antegrade cerebral perfusion is instituted for graft–innominate artery and distal aortic anastomoses. Proximal graft is then clamped, and full cardiopulmonary flow reinstituted. Proximal anastomosis is completed during rewarming. Left subclavian artery is typically ligated at end of procedure through sternotomy to avoid competitive flow with left carotid–subclavian arterial bypass. Thoracic endograft is used to complete arch replacement, with distal aortic graft as proximal landing zone.

TEVAR cases, the stent was placed through a 24F sheath positioned in the femoral artery, and radiopaque markers on the custom aortic graft simplified the precise positioning for deployment. The decision to perform the TEVAR in a staged or concomitant manner was made by the attending surgeon on clinical grounds.

Staged TEVAR was performed through the common femoral artery on postoperative day 3 to 7 at a clinically convenient time. Lumbar drain placement was performed routinely for all patients undergoing staged TEVAR. A 22F or 24F sheath was placed into the femoral artery. A standard pigtail catheter was used to help determine appropriate stent graft lengths. A GORE-TAG stent device was advanced through the sheath and into the aortic graft with the guidance of radiopaque markers as the margin of the proximal landing zone (Figure 1). The stent graft was deployed and then dilated with a GORE trilobed balloon (W. L. Gore) proximally and distally. Arch angiography was performed to confirm positioning of the stent graft and successful exclusion of the aneurysm. Additional stent grafts were placed if necessary. The femoral artery cannulation site was closed with a PROSTAR suture closure device ($n = 3$; Abbott Laboratories, Abbott Park, Ill) or by direct surgical repair ($n = 4$).

TABLE 1. Preoperative study group characteristics

	Group I ($n = 28$)	Group II ($n = 9$)	<i>P</i> value
Age (y, mean $\pm$ SD)	64.7 $\pm$ 15.0	63.0 $\pm$ 18.7	.78
Male (No.)	17 (61%)	5 (56%)	>.99
Diabetes mellitus (No.)	5 (18%)	1 (11%)	>.999
Renal insufficiency (No.)	8 (29%)	1 (11%)	.40
Chronic obstructive pulmonary disease (No.)	6 (21%)	1 (11%)	.66
Reoperative surgery (No.)	10 (36%)	3 (33%)	>.999
Type A or B dissection (No.)	18 (64%)	3 (33%)	.14
Aneurysm size (cm, mean $\pm$ SD)	6.4 $\pm$ 1.6	5.7 $\pm$ 1.3	.23

Fisher's Exact Test (2-sided) was used for categorical variables and independent *t* test (2-sided) was used for continuous variables.

Postoperative Care and Follow-up

The postoperative course and complications related to surgery were determined from retrospective review of inpatient and outpatient medical records. Group II patients undergoing TEVAR underwent serial computed tomographic imaging at 1 month, 6 months, and then yearly thereafter to screen for the presence of endoleaks and ensure appropriate aneurysmal regression. The last follow-up date for the purposes of this study was July 1, 2009.

Statistical Analysis

Comparisons between groups of preoperative, intraoperative, and postoperative variables were performed with Fisher's exact tests (2-sided) for categorical variables and independent *t* tests (2-sided) for continuous variables. Continuous variables are reported as a mean $\pm$ SD. Statistical analyses were performed with SPSS version 17.0 software (SPSS Inc, Chicago, Ill).

RESULTS

Table 1 depicts the preoperative characteristics of the patient groups. The patient groups were of similar composition in terms of mean age and comorbidities. One third of the patients in each group had previously undergone sternotomy. There was a trend toward a higher rate of aortic dissection in group I (64% vs 33%, $P = .14$).

Table 2 shows the intraoperative characteristics of groups I and II. Forty-six percent of group I and 56% of group II underwent some concomitant cardiac procedures ($P = .71$). Eighteen of group I patients and 44% of group II patients underwent concomitant valve-sparing aortic root replacement ($P = .18$).

The hybrid arch repair permitted us to eliminate completely the use of HCA in group II, whereas conventional open repair in group I required HCA in 82% of patients ($P < .0001$). The 5 patients in group I who had the procedure done exclusively with SACP had favorable anatomy amenable to such an approach (bovine arch with the left carotid artery origin off of the innominate trunk). There was also a significantly shorter duration of SACP required in group II than in group I (18.9 ± 9.2 minutes vs 33.3 ± 13.7 minutes, $P = .007$), as well as shorter CPB (152 ± 41.5

TABLE 2. Intraoperative study group characteristics

	Group I (n = 28)	Group II (n = 9)	P value
Concomitant procedure (No.)	13 (46%)	5 (56%)	.71
Valve-sparing procedure* (No.)	5 (18%)	4 (44%)	.18
Axillary cannulation (No.)	27 (96%)	9 (100%)	>.999
Use of HCA (No.)	23 (82%)	0 (0%)	<.001
HCA time (min, mean $\pm$ SD)	23.3 $\pm$ 12.8	0 $\pm$ 0	.004
Use of SACP (No.)	24 (86%)	9 (100%)	>.999
SACP time (min, mean $\pm$ SD)	33.3 $\pm$ 13.7	18.9 $\pm$ 9.2	.007
Cardiopulmonary bypass time (min, mean $\pm$ SD)	218.0 $\pm$ 66.7	152.0 $\pm$ 41.5	.009
Aortic crossclamp time (min, mean $\pm$ SD)	108.5 $\pm$ 32.0	80.4 $\pm$ 43.1	.043
Packed red blood cells (units, mean $\pm$ SD)	3.5 $\pm$ 3.7	4.1 $\pm$ 2.1	.64

Fisher's Exact Test (2-sided) was used for categorical variables and independent *t* test (2-sided) was used for continuous variables. HCA, Hypothermic circulatory arrest; SACP, selective antegrade cerebral perfusion. *Valve-sparing procedures were defined as a David procedure or an ascending aortic replacement with concomitant aortic valve repair.

minutes vs 218 ± 66.7 minutes, $P = .009$) and aortic cross-clamp (80.4 ± 43.1 minutes vs 108.5 ± 32.0 minutes, $P = .043$) times (Figure 3).

There were no significant differences between groups I and II with regard to postoperative outcomes (Table 3). There were no neurologic complications, defined as stroke or signs or symptoms of spinal cord ischemia, in the hybrid group. In the conventional group, 11% of patients had stroke occur, and 7% of patients had spinal cord ischemia, for a total neurologic complication rate of 14% (1 patient had both complications). This difference did not achieve statistical significance. Technical success was achieved in 100% of cases in the hybrid group with concomitant or staged TEVAR. There have been no endoleaks in the group II patients, who have been followed up for a mean of 7.4 ± 5.5 months. The 30-day and in-hospital mortalities for group

TABLE 3. Postoperative study group characteristics

	Group I (n = 28)	Group II (n = 9)	P value
Intensive care unit stay (d, mean $\pm$ SD)	11.1 $\pm$ 18.9	6.4 $\pm$ 6.4	.48
Hospital stay (d, mean $\pm$ SD)	17.9 $\pm$ 20.3	14.8 $\pm$ 9.6	.66
Neurologic complications* (No.)	4 (14%)	0 (0%)	.55
Death (No.)	5 (18%)	1 (11%)	>.999

Fisher's Exact Test (2-sided) was used for categorical variables and independent *t* test (2-sided) was used for continuous variables. *Neurologic complications were defined as a stroke or signs or symptoms of spinal cord ischemia.

I patients were 11% and 18%, respectively, compared with 11% and 11% for group II patients ($P = .54$, $P = .76$).

DISCUSSION

There have been consistent improvements in the operative strategies used to address aortic arch and proximal descending aortic aneurysm and dissection repairs,^{7,8} but the perioperative morbidity and mortality associated with conventional 1- or 2-stage procedures remain high.¹ The mortality risks have been reported as 5% for the first-stage operation, 4% for the intervening interval, and 6% for the second-stage repair.¹ The risks of neurologic complications related to HCA and extensive SACP times also remain a substantial burden in conventional TAAR. As a result, less invasive means of completing the TAAR have been sought with the use of thoracic aortic endografting.^{3-6,9} Such an approach may shorten the interval required for recovery before the second-stage intervention and lessen the risks inherent in the delay until final repair. Still, completion rates with hybrid strategies remain less than optimal, with 1 study reporting a rate of 78% with a second-stage TEVAR approach.¹⁰

We have introduced a hybrid approach to TAAR that uses left CSB and an open subtotal aortic arch replacement with either concomitant or staged thoracic stent grafting to achieve a hybrid TAAR with relatively short periods of SACP and without the use of HCA. This approach appears to be both feasible and safe through short-term follow-up and avoids the need for a second open surgical procedure, which is conventionally required with "elephant trunk" repairs of the aortic arch and descending aorta. The aortic graft serves as a relatively long proximal landing zone that makes the TEVAR procedure relatively straightforward and reproducible, minimizing the risks of incomplete arch repairs. In our small series, this approach was associated with significant decreases in the duration of SACP, CPB, and aortic crossclamping, and it eliminated the need for HCA relative to open conventional TAAR.

This hybrid approach is fully compatible with root reconstructions and valve-sparing root replacements. In addition, 33% of our hybrid series were for ascending or arch dissections, meaning that the technique will be applicable to

FIGURE 3. Group II had significantly shorter selective antegrade cerebral perfusion (SACP), cardiopulmonary bypass (CPB), and aortic crossclamp times than did group I.

emergency operations once the approach has been standardized. Although we did not find a statistically significant decrease in neurologic complications, the avoidance of HCA and the relatively short SACP times imply that protective benefits might be seen in larger series. Future multicenter studies will evaluate this potential.

Several benefits are conferred by the left CSB as part of this technique. These include the avoidance of the left subclavian artery–graft anastomosis through a sternotomy, which is usually technically challenging and unduly prolongs HCA. In addition, left CSB allows flow from the left subclavian to left carotid artery during the left carotid artery–graft anastomosis, meaning that neither HCA nor SACP is required for this interval. Left CSB also allows the graft–distal aorta anastomosis to be performed between the left carotid and left subclavian takeoff and therefore more proximally than in conventional arch repairs (after the takeoff of the left subclavian artery). This typically means that the distal anastomosis is performed with better visualization and relative ease, minimizing the SACP time required. The left subclavian artery is ligated at the end of the open procedure, and the distal aortic graft serves merely as the proximal landing zone for the TEVAR, so it is not as important as with conventional repairs that its location be as distal as possible.

We prefer to ligate the left subclavian artery during the open procedure, as opposed to occluding it later at the time of stent graft placement (eg, with coil or Amplatzer device embolization). We believe that flow into the left subclavian artery from its native origin could compete with flow from the CSB in the interim between the open and endovascular stages of the repair. This could hypothetically lead to stasis of blood in the CSB graft and increase the risk of graft thrombosis. For open procedures with concomitant stent grafting, we believe that it is more feasible to ligate the left subclavian artery with an endovascular stapler through the sternotomy than to access the left brachial artery for endovascular ligation.

The optimal timing of the TEVAR in relation to the open portion of hybrid arch reconstructions still remains to be determined, and single-stage and dual-stage interventions have been reported.^{10,11} The advantages of a concomitant procedure are the avoidance of transfemoral arterial access and of the staging of the procedure. Such an approach is simplified with the use of a custom graft with an additional side arm amenable to the antegrade deployment of a thoracic endograft. The disadvantages include the necessity of a hybrid operating room (or at least an operating room with a high-resolution C-arm for intraoperative fluoroscopy) and the potential for prolonging the operative time of a complex, open procedure. If the TEVAR is to be staged and performed by a transfemoral approach, radiopaque markers and the long proximal landing zone (within the aortic graft) that is of known size do make this quite feasible for performance during the same patient admission. This is witnessed by our 100% technical success rate of

TEVAR in our group II patients, with no endoleaks through a mean follow-up of 7 months.

The limitations of our study include all the caveats of a small, non-randomized, retrospective study with limited follow-up. The power of our series to detect differences in neurologic outcomes was low, not surprisingly as this was a feasibility study aiming to introduce and refine our surgical technique. Because of the extensive morbidity and mortality associated with conventional open approaches, however, we have currently abandoned open approaches and moved to our described hybrid TAAR technique for all cases of TAAR, with the exception of patients with connective tissue disorders. All patients (but particularly younger patients) are counseled preoperatively concerning the need for long-term imaging surveillance with the hybrid approach and that the long-term durability of endovascular stent grafts used in this regard remain unproven. The durability of TEVAR will be evaluated with future studies comparing the long-term outcomes of conventional and hybrid arch repairs. All these patients will require serial imaging and close patient follow-up to ensure appropriate aneurysm regression and exclusion. Additional follow-up is needed, and future studies will include standardized definitions for neurologic complications and other adverse events, as well as additional outcome measures (eg, patient satisfaction, quality of life, neurocognitive assessment, and cost). The integration of TEVAR into TAAR remains an experimental approach, because thoracic stent grafts such as the GORE-TAG device have not received formal approval for this purpose.

In summary, left CSB before an open subtotal aortic arch replacement with concomitant or staged thoracic stent grafting to achieve hybrid TAAR was associated with decreases in SACP, CPB, and aortic crossclamp times and eliminated the need for HCA. This technique may decrease the risk of neurologic complications associated with TAAR and provide a viable hybrid approach to patients with aortic arch aneurysms and dissections.

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Discussion

Dr John A. Kern (Charlottesville, Va). Dr Xydas, I congratulate you on a nice presentation and study. Looking back at your last 330-odd aortic patients, as you point out, 37 underwent TAAR procedures with good results. With the advent of endovascular technology, your group, like many groups, is getting creative in ways to minimize circulatory arrest times, minimize cerebral malperfusion times, and improve outcomes, and certainly with this study and this small group of patients you have done that. You have certainly demonstrated decreased CPB, crossclamp, and circulatory arrest times. I really have just a few questions, some of which are technical. Tell me about the CSB. Did you always do that concomitantly with the arch procedure, or did you do that a day or so before? In addition to that, because it appears that it is routine, because you are using the CSB to maintain carotid perfusion, did you necessarily image the head to define the cerebrovascular anatomy?

Dr Xydas. We do the left CSB in the same setting and start off our procedure with it in the operating room. The rationale for this is that potentially if it was done earlier, even over the weekend or a couple of days, graft patency might be diminished if there was competitive flow. In terms of the rationale for doing the left CSB, it is really 2-fold. One reason is in doing the carotid anastomosis through the sternotomy, it allows us protection with the subclavian-carotid flow during that span. So the anatomy is not necessarily something to which we have to react. We did not do any cerebral imaging other than the standard preoperative computed tomographic angiography. The second reason for doing the bypass is that it eliminates the need for doing the subclavian-graft anastomosis in the chest, which is typically difficult in a deep hole with imperfect visualization.

Dr Kern. Your mean follow-up time naturally was around 7 months, as you point out, and I imagine most of these patients are older. Certainly the CSB is the easier operation. This is almost a complete TAAR, so I really congratulate you on avoiding the arch debranching procedures, which establish blood flow to the great vessels through a smaller graft coming off the ascending aorta. I think the durability of this procedure is going to be quite good; however, with the CSB over time, you can't be sure. In the TEVAR

group, the second group, you have done the endograft both simultaneously and staged in that small group, is that right?

Dr Xydas. Yes, this is correct.

Dr Kern. Do you have any preferences, do you have anything you can tell us about when you prefer to do it at the same time versus when you stage it?

Dr Xydas. This issue requires ongoing work, and there are no clear winners in terms of how to approach this. We did this partly on clinical grounds but also on administrative grounds in terms of whether the hybrid room was available for doing the procedure concomitantly versus in a staged manner. If there was an extensive concomitant procedure expected, however, we did opt to do it in a staged approach. Only 2 of 9 patients underwent the procedure concomitantly, with the other 7 undergoing it in a staged fashion. Again, however, I think that only future research in this area will enlighten us as to which approach is going to be better. It was interesting at this meeting to hear from Dr Griep's group, which presented data suggesting that performing it in a staged fashion past 5 to 7 days may decrease the incidence of spinal cord ischemia or other neurologic issues. In terms of the patency of the left CSB, once you are in the postoperative phase, our expectation is that even if the patency rates of these grafts are low, this is not going to affect the patients neurologically in that many patients undergoing TEVAR actually have their left subclavian artery occluded and covered with the TEVAR without a bypass and seem to do relatively well. Staging it enough to allow collateralization to some degree will probably diminish even further the effect of left carotid-subclavian graft patency on long-term neurologic outcome.

Dr Kern. For those couple of patients who underwent concomitant stent grafting, did you use a lumbar drain? Did they undergo extensive enough stent grafting that you used a lumbar drain?

Dr Xydas. The patients who underwent concomitant procedures had a lumbar drain. Patients who underwent the staged procedure also had lumbar drains routinely, even if they didn't require extensive stenting across the descending aorta.

Dr Joseph E. Bavaria (Philadelphia, Pa). Do you coil out your left subclavian at the end?

Dr Xydas. We do occlude the proximal left subclavian artery at the end of the procedure. If it is easy to approach through the sternotomy, we either staple it or ligate it. If not, we approach it endovascularly at the time of the TEVAR through a staged approach.

Dr Bavaria. Also, you can't put a large GORE graft through an 8-mm graft. So are you using small grafts? We usually use a 10-mm side arm.

Dr Xydas. We are actually using a 9-mm side branch on our custom aortic grafts for use with concomitant TEVAR procedures with both small and large stent grafts.

Dr Lars G. Svensson (Cleveland, Ohio). Thank you, Dr Xydas. This is an interesting field, and maybe some people should get together and do a multicenter study on this, because there are a lot of evolving issues here, as you brought up.

Dr Xydas. Thank you.