Aneurysmal expansion of the visceral patch after thoracoabdominal aortic replacement: An argument for limiting patch size?

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Introduction: **Thoracoabdominal aortic replacement requires visceral vessel revascularization and is usually performed with Crawford's inclusion technique or a large Carrel patch. This segment of retained native aorta may be prone to recurrent aneurysmal disease. We reviewed our experience with patients in whom aneurysmal expansion of the visceral patch was detected.**

Methods: **The records of 107 patients undergoing thoracoabdominal aortic replacement operations performed or followed up at the Johns Hopkins Hospital between 1992 and 2000 were reviewed. All patients had visceral patches created for type II, III, or IV aneurysms. Visceral patches were considered aneurysmal if the maximal diameter of the aortic prosthesis and patch was 4.0 cm or more.**

Results: **Patch aneurysmal expansion (mean, 5.4 cm) was detected in eight patients (7.5%). All three women had connective tissue disorders (mean age, 36 years), and all five men had atherosclerotic disease (mean age, 73 years). Five patients were symptom free with their aneurysms detected by surveillance computed tomography scans; two patients had back pain prompting computed tomography scans; and one patient presented with an emergency patch rupture. Aneurysmal patches were successfully revised in three patients. Two patients died in the operating room, and three patch aneurysms (< 5 cm) are still being observed. The mean time to the detection of aneurysmal expansion was 6.5 years after the original operation. Therapy consisted of replacement of a segment of the thoracoabdominal aortic graft and refashioning a smaller patch, including only the visceral artery orifices with separate attachment of the left and possibly right renal artery.**

Conclusions: **Although Crawford's inclusion method of visceral patch construction is generally durable, patients undergoing thoracoabdominal aortic replacement require yearly surveillance for the detection of aneurysmal expansion of the visceral patch. We recommend limiting visceral patch size at the original operation by routinely excluding the orifice of the left renal artery. Patients at high risk for recurrent aneurysmal expansion, such as those with connective tissue disorders, will benefit from creating small visceral patches and possibly implanting both renal arteries separately during the original operation. (J Vasc Surg 2001;34:405-10.)**

Thoracoabdominal aortic aneurysms (TAAAs) comprise 2% to 5% of aortic aneurysms, representing the more extensive end of the spectrum of aneurysmal disease. The inclusion technique of Crawford,[1] in which the visceral and intercostal arteries are directly anastomosed to the polyester fiber (Dacron) graft, is a central component of modern thoracoabdominal aneurysm repair, enabling approximately 60% survival at 5 years after operation in modern series.[2]

Although hypertension and smoking are present in most patients with aneurysmal disease, patients with thoracoabdominal aneurysms have a greater prevalence of aortic dissection, connective tissue disorders, female sex, and multiple aneurysms.[2,3,5-13] This distribution of patient risk factors may reflect a greater presence of aortitis, cystic medial necrosis, or infection in patients with TAAAs.[3,6,14] Therefore, patients with TAAAs may be at increased risk for aneurysmal degeneration of any segment of their aorta. Of note, Crawford's inclusion technique used during TAAA repair leaves a small amount of native perivisceral aorta, similar to a Carrel patch, that is at risk for subsequent aneurysmal dilation. Because this segment of retained native aorta may be prone to recurrent aneurysmal disease, we reviewed our experience with patients in whom thoracoabdominal aortic replacement was performed with the Crawford inclusion technique for the visceral vessel patch to determine the prevalence of subsequent aneurysmal expansion of the visceral aortic segment.

From the Division of Vascular Surgery, Department of Surgery, Johns Hopkins Hospital.
Competition of interest: nil.
Presented at the Southern Association for Vascular Surgery Twenty-fifth Annual Meeting, Rio Grande, Puerto Rico, Jan 24-27, 2001.
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0741-5214/2001/$35.00 + 0 **24/6/117149**
doi:10.1067/mva.2001.117149

METHODS

The records of all patients undergoing thoracoabdominal aortic replacement operations performed at the Johns Hopkins Hospital between 1992 and 2000 were reviewed. The records of all actively followed up

Patients with visceral patch aneurysms after thoracoabdominal aortic replacement*

Patient	*Age*	*Race*	*Sex*	*Smoking history*	*Hypertension*	*Connective tissue disorder*	*Previous dissection*	*Crawford class*	*Original patch*
1	71	White	Male	Yes	No	No	No	III	c/s/Rr
2	43	White	Female	Yes	No	Marfan	No	IV	c/s/Re/Lr
3	70	White	Male	Yes	Yes	No	No	II	c/s/Rr/Lr
4	28	Black	Female	Yes	Yes	Yes-unspecified	Yes	III	c/s/Rr/Lr
5	69	Black	Male	Yes	Yes	No	Yes	II	c/s/Rr
6	38	White	Female	No	No	Marfan	Yes	III	c/s/Rr/Lr
7	87	Black	Male	No	Yes	No	No	II	c/s/Rr
8	68	White	Male	Yes	No	No	No	III	c/s/Rr

*Patients 1 through 5 underwent surgical repair of the aneurysm, and patients 6 through 8 are currently being observed.
†Hospital stay is postoperative days only.
c, Celiac axis; *EBL,* estimated blood loss (L); *ICU,* intensive care unit; *Lr,* left renal artery; *Rr,* right renal artery; *s,* superior mesenteric artery.

patients, including those patients whose original aortic operation was performed elsewhere (n = 2), were also reviewed.

Thoracoabdominal aortic replacement operations were performed and followed up in 229 patients. Crawford's inclusion technique was used to directly anastomose the origins of the visceral and renal vessels to the Dacron graft.[1] The celiac, superior mesenteric, and right renal arteries were typically included in the patch, as well as the left renal artery if anatomically feasible. Patients were excluded if no visceral patch was created by the Crawford inclusion technique, such as with type I aneurysms or tailoring procedures for dissection. Thus, our study population consisted of 107 patients with visceral patches that were created for type II, III, and IV aneurysms.

Routine follow-up for patients included yearly computed tomography (CT) scans with three-dimensional reconstruction. The interval until the next CT scan was reduced to 6 months if a rapid increase in aneurysm expansion rate (> 0.4 cm/y) was noted. Visceral patches were considered to be aneurysmal if the total maximal diameter of the aortic prosthesis and patch in any single dimension was 4.0 cm or more. This definition of a patch aneurysm was selected to approximate a 50% increase in diameter compared with #26 or #28 aortic grafts, the most common sizes that we place. Visceral patch aneurysms were considered for operative repair if the largest diameter was 5.0 cm or more.

Statistical comparison for categorical variables was performed with the Fisher exact test. *P* values were considered significant if they were .05 or less.

RESULTS

Of 229 patients undergoing and being followed up after TAAA repair at the Johns Hopkins Hospital, 107 patients had visceral patches created with the Crawford inclusion technique. The original aneurysms were Crawford class II in 46 (43%) patients, class III in 54 (50%) patients, and class IV in 7 (7%) patients. Connective tissue disorders, most commonly Marfan syndrome, were a risk factor in 17 (16%) patients, whereas atherosclerotic disease was present in 90 (84%) patients.

Compliance with postoperative surveillance was 100% among the 107 patients. Patch aneurysmal expansion was detected in eight patients (ie, 7.5% prevalence) (Table). All eight patients had aortic grafts placed at their initial operation that were 30 mm or less in diameter. All three women had connective tissue disorders (mean age, 36 years), and all five men had atherosclerotic disease (mean age, 73 years). The greater number of visceral patch aneurysms present in patients with connective tissue disorders (17.6%), compared with patients with atherosclerotic disease (5.6%), was statistically significant ($P = .034$, Fisher exact test).

Five patients were symptom free with aneurysms detected by surveillance CT scans; two patients had back pain prompting CT scans before their scheduled yearly visit; and one patient presented with an emergency patch rupture. Representative CT scans are shown in Figs 1 through 4. The mean time to detection of aneurysmal expansion was 6.5 years after the original operation, and the mean patch aneurysm size was 5.4 cm.

Five patients were operated on to revise the visceral patch (Table). The mean patch aneurysm size was 6.2 cm in these patients. Aneurysmal patches were successfully revised in three patients. Therapy consisted of replacing a segment of the thoracoabdominal aortic prosthetic graft and refashioning a smaller patch, placing the sutures in the orifices of the vessels. The left renal artery was implanted separately as was the right in one patient. After lengthy and expensive hospitalizations (Table), these patients are well in routine follow-up.

Two patients died in the operating room. One patient presented with frank rupture and hemodynamic instability; although he was operated on immediately, he was unable to be resuscitated successfully. The other patient had a massive myocardial infarction just as the patch repair was finished and was unable to be revived despite aggressive therapy.

Presentation	*Aneurysm size (cm)*	*Detection time (y)*	*Revised patch*	*EBL*	*ICU stay (d)*	*Hospital stay (d)†*	*Hospital charge*
Back pain	6.0	6	c/s/Rr	10 L	15	20	$86,181
Back pain	6.0	6	c/s	19 L	18	24	$110,660
Asymptomatic	6.5	11	c/s/Rr	12 L		Died	$14,102
Asymptomatic	5.0	5	c/s/Rr	26 L	12	23	$87,987
Rupture	6.1	4		11 L		Died	$6,326
Asymptomatic	4.0	13					
Asymptomatic	4.9	3					
Asymptomatic	4.3	5					

Three patients had patch aneurysms (mean, 4.4 cm) that were detected and are still being regularly followed with imaging studies (Table). Two patients are being followed up with annual CT scans and a third (4.9 cm) with biannual CT scanning.

CONCLUSIONS

Crawford's inclusion technique was a landmark in the history of modern thoracoabdominal aneurysm repair, allowing safe performance and, ultimately, long-term survival after TAAA repair. However, patients with a tendency to form these extensive aneurysms may continue to exhibit aneurysmal degeneration of any unrepaired segment of their aorta, even in the small amount left by the inclusion technique. Although this technique appears to give durable results for most patients, we report a series of eight patients in whom the small amount of native perivisceral aorta used for the inclusion patch subsequently expanded and, in one patient, ruptured.

Repair of the visceral patch aneurysm was a morbid undertaking. Two of the five patients taken for operative repair died on the operating room table, and among survivors, there was a long intensive care unit and hospital length of stay. We noted extensive adhesions around the visceral patch in all cases, perhaps contributing to difficult dissection and extensive blood loss. Nevertheless, survival and meaningful quality of life are certainly possible and should be offered to selected patients.

We used the criteria of 5.0 cm as our threshold for operative repair of a visceral patch aneurysm, similar to the consensus for an infrarenal abdominal aortic aneurysm. On this basis, we follow up patients with small visceral patch aneurysms (<5 cm) with annual or biannual abdominal CT scans. However, it is not clear whether the threshold for operation should remain 5.0 cm, given the high morbidity of surgical repair of patch aneurysms. Because the only patient in this series to present with a ruptured visceral patch aneurysm had an aneurysm diameter greater than 6 cm (Table), it may be reasonable to raise the threshold for operative repair to 6 cm, at least for patients without connective tissue disorders. However, because visceral patch aneurysms may behave like saccular and not fusiform aneurysms (Figs 1, 3, and 4), we continue to consider operative repair at 5 cm diameter. Additionally, the optimal surveillance interval is unclear because the growth rate of patch aneurysms is currently unknown.

Only two patients with aneurysmal dilation of the visceral patch have been reported in the literature. One patient was reported as part of a series of patients with ruptured TAAAs.[15] This patient was observed, although the length of time to detection of patch expansion and the current size were not mentioned. The second reported case of visceral patch expansion occurred 1 month postoperatively in a 34-year-old patient with Marfan syndrome.[16] The dilated patch was consistent with a pseudoaneurysm, rupturing at its proximal suture line, and was repaired with complete abdominal aortic replacement with Dacron, left nephrectomy, and separate grafts to the celiac, super mesenteric, and right renal arteries.

Although we refashioned smaller inclusion patches to repair the aneurysm in all cases, separate grafts to each visceral vessel with complete exclusion of all native aorta would be another approach.[16] This approach may be amenable to correction by endovascular means (K. Craig Kent, personal communication).

We report a 7.5% prevalence of visceral patch expansion among patients who underwent thoracoabdominal aortic operation with creation of a visceral patch. We suspect that recurrent aneurysm formation is underreported and suggest annual surveillance of all patients after TAAA repair. In this study we excluded patients with type I aneurysms as well as any other type that was repaired with a beveled anastomosis rather than a complete visceral patch. However, it is likely that even these patients are at risk for further aneurysm formation at the visceral segment and would also need surveillance.

The mechanism of recurrent aneurysm formation in the visceral patch is unclear. Patients with connective tissue disorders, such as Marfan syndrome comprise almost half of the cases reported here and are clearly at increased risk for this process. Indeed, we found that almost 18% of patients with connective tissue disorders ultimately underwent visceral patch expansion compared with only 5.6% of patients with atherosclerotic disease. However, more than half of our patients had TAAAs associated with atherosclerosis, suggesting that all patients with TAAA repair are at risk for recurrent aneurysm formation. It is unclear whether biochemical differences in collagen and elastin distribution in the visceral aortic segment[17] are responsible for this process.

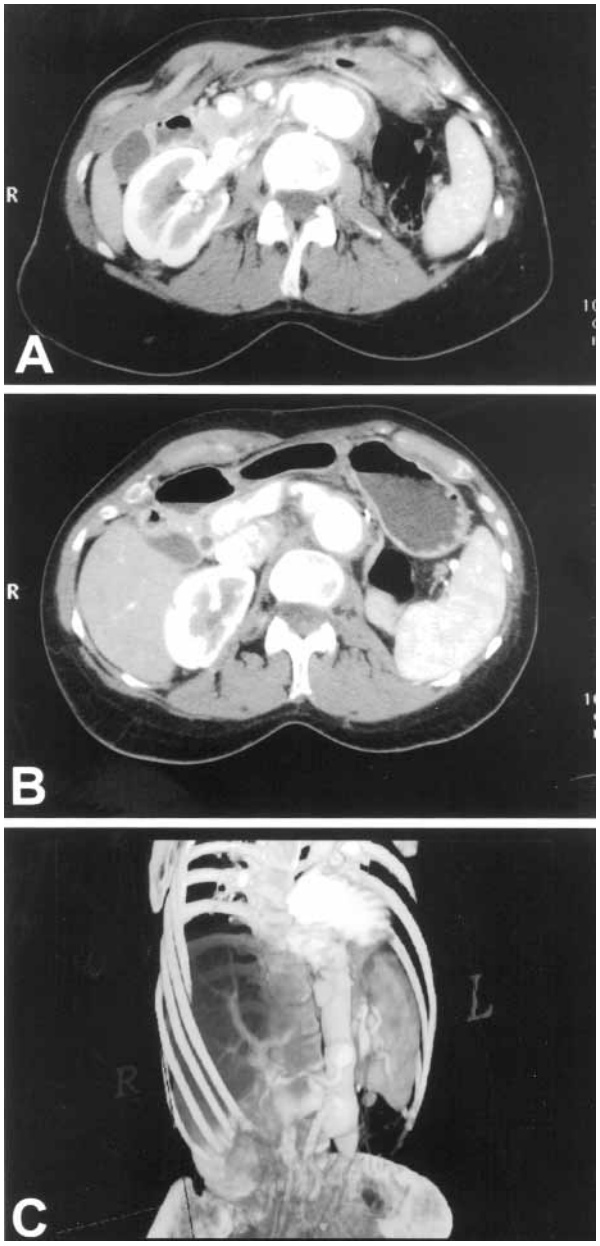

Fig 1. CT scans of patient with visceral patch aneurysm, unoperated. **A,** Patch aneurysm near right renal artery. **B,** Patch aneurysm near SMA. **C,** Three-dimensional CT scan rotation focusing on SMA and right renal artery orifices. *CT,* Computed tomography; *SMA,* superior mesenteric artery.

Fig 2. Three-dimensional CT scan of patient 2 demonstrating expansion of visceral patch.

Fig 3. CT scan of patient 5 demonstrating ruptured patch aneurysm with surrounding hematoma.

We recommend that patients who undergo operation for thoracoabdominal aortic replacement continue yearly surveillance imaging to detect aneurysmal expansion of the visceral patch. Although half of the patients in this report already had separate left renal artery reimplantation at their original operation, we also recommend limiting visceral patch size at the original operation by routinely reimplanting the left renal artery separately, if anatomically possible. Patients at high risk for recurrent aneurysmal expansion, such as those with connective tissue disorders, will benefit from the creation of small visceral patches and possibly the implantation of both renal arteries separately during the original operation.

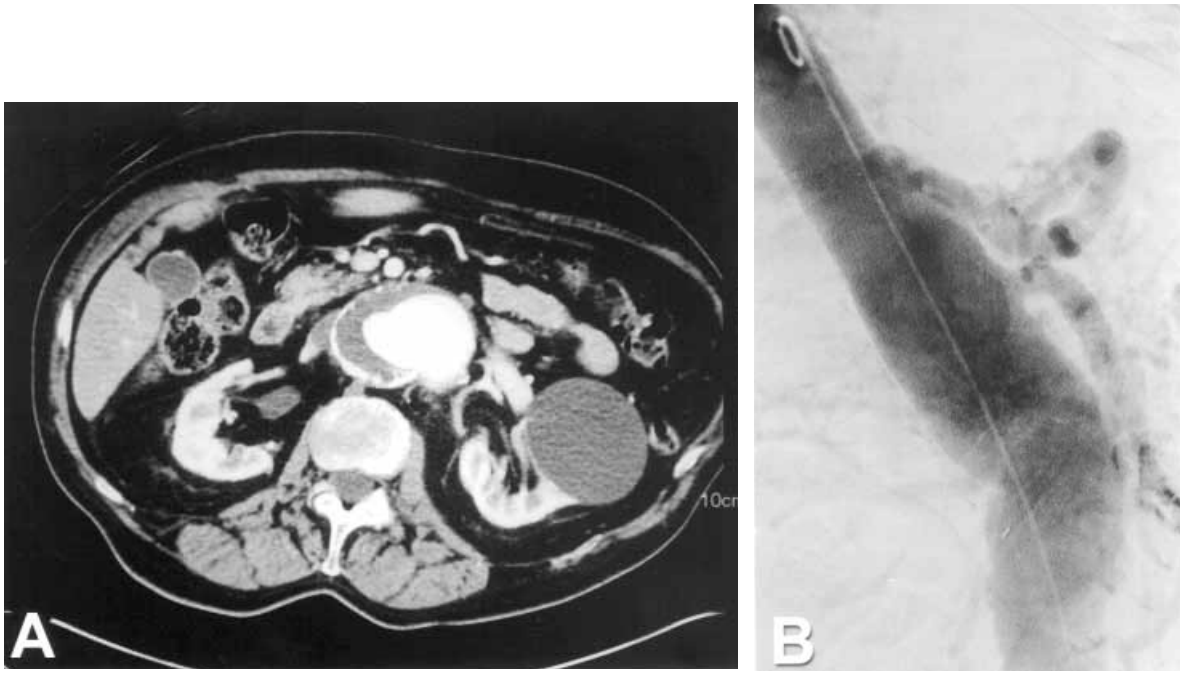

Fig 4. A, CT scan of patient 3 demonstrating thrombus within patch aneurysm. **B,** Lateral view of angiogram of same area.

REFERENCES

1. Crawford ES. Thoracoabdominal and abdominal aortic aneurysm involving renal, superior mesenteric, and celiac arteries. Ann Surg 1974;213:417-26.
2. Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg 1993;17:357-70.
3. Cambria RP, Davison JK, Zannetti S, L'Italien G, Atamian S. Thoracoabdominal aneurysm repair: Perspectives over a decade with the clamp-and-sew technique. Ann Surg 1997;226:294-305.
4. Hallet JW, Marshall DM, Petterson TM, Gray DT, Bower TC, Cherry KJ Jr, et al. Graft-related complications after abdominal aortic aneurysm repair: reassurance from a 36 year population-based experience. J Vasc Surg 1997;25:277-86.
5. Dardik A, Lin JW, Gordon TA, Williams GM, Perler BA. Results of elective abdominal aortic aneurysm repair in the 1990s: a population-based analysis of 2,335 cases. J Vasc Surg 1999;30:985-95.
6. Acher CW, Wynn MM, Hoch JR, Kranner PW. Cardiac function is a risk factor for paralysis in thoracoabdominal aortic replacement. J Vasc Surg 1998;27:821-30.
7. Bickerstaff LK, Pairolero PC, Hollier LH, Melton LJ, Van Peenen, Cherry KJ, et al. Thoracic aortic aneurysms: a population-based study. Surgery 1982;92:1103-8.
8. Coselli JS, LeMaire SA, Poli de Figueiredo L, Kirby RP. Paraplegia after thoracoabdominal aortic aneurysm repair: is dissection a risk factor? Ann Thorac Surg 1997;63:28-36.
9. Cox GS, O'Hara PJ, Hertzer N, Piedmonte MR, Krajewski LP, Beven EG. Thoracoabdominal aneurysm repair: a representative experience. J Vasc Surg 1992;15:780-8.
10. Johansson G, Markstrom U, Swedenborg J. Ruptured thoracic aortic aneurysms: a study of incidence and mortality rates. J Vasc Surg 1995;21:985-8.
11. Perko MJ, Norgaard M, Herzog TM, Olsen PS, Schroeder TV, Pettersson G. Unoperated aortic aneurysm: a survey of 170 patients. Ann Thorac Surg 1995;59:1204-9.
12. Safi HJ, Campbell MP, Muller CC, Iliopoulos DC, Khoynezhad A, Letsou GV, et al. Cerebral spinal fluid drainage and distal aortic perfusion decrease the incidence of neurological deficit: the results of 343 descending and thoracoabdominal aortic aneurysm repairs. Eur J Vasc Endovasc Surg 1997;14:118-24.
13. Svensson LG, Hess KR, Coselli JS, Safi HJ. Influence of segmental arteries, extent and atriofemoral bypass on postoperative paraplegia after thoracoabdominal aortic operations. J Vasc Surg 1994;20:255-62.
14. Panneton JM, Hollier LM. Basic data underlying clinical decision making: non-dissecting thoracoabdominal aortic aneurysms: part I. Ann Vasc Surg 1995;9:503-14.
15. Quinones-Baldrich WJ, Nene SM, Gelabert HA, Moore WS. Rupture of the perivisceral aorta: atherosclerotic versus mycotic aneurysm. Ann Vasc Surg 1997;11:331-41.
16. Carrel TP, Signer C. Separate revascularization of the visceral arteries in thoracoabdominal aneurysm repair. Ann Thorac Surg 1999;68:573-5.
17. Halloran BG, Davis VA, McManus BM, Lynch TG, Baxter BT. Localization of aortic disease is associated with intrinsic differences in aortic structure. J Surg Res 1995;59:17-22.

Submitted Jan 9, 2001; accepted Apr 5, 2001.

DISCUSSION

Dr Larry Hollier (New York, NY). Dr Dardik and his colleagues are certainly to be congratulated for bringing to the attention of the vascular community a serious but unappreciated problem, that of late development of aneurysms of the reimplanted aortic patch. We do agree with you that this is probably underreported.

The authors reported an incidence of patch aneurysm in 7.5% of patients. This certainly seems higher than the rate generally appreciated by most of us who do thoracoabdominal surgery. What is even more disturbing is that, in the Marfan patient, over 17% of these had patch aneurysms. One has to ask how safe is the Crawford technique!

In my own experience now with more than 500 thoracoabdominal aneurysm repairs, I am aware of 11 patch aneurysms in my patients, an incidence of roughly 2.2%. Obviously I may be missing follow-up of many of these patients. Two aneurysms in this group occurred in the intercostal patch. Both have been followed without rupture occurring, at least to the present. The remainder had aneurysms develop in the visceral patch, two occurring in patients with collagen disorders, one with Marfan, and one in a patient with Ehlers-Danlos. The patient with Marfan ruptured but survived emergency repair. The Ehlers-Danlos patient underwent successful secondary elective revascularization of the visceral vessels with separate grafts, and we repaired the aneurysm at the site of the visceral cuff with an endovascular stent-graft. The remaining patients with visceral patch aneurysms had degenerative disease, three rupturing and undergoing emergency operation, with one dying during the attempted repair. As I said, there are likely others about whom I am unaware.

In view of this paper presented today, I have to conclude that most of us have not been following these patients closely enough postoperatively. We are generally so happy to have the patient survive the operation that little thought is given to ever considering these patients for repeat operation. Obviously this is an error, and I now believe that we need to establish a formal protocol for follow-up of these patients, but the timing is unclear.

My first question of the authors relates to such follow-up. Your median time to develop was 6½ years. Do you really need a postoperative CT scan yearly? This seems excessive. How many of your patients actually followed this regimen, and would not a CT scan every 2 to 3 years be sufficient?

My next comment relates to your recommendation for a smaller Carrel patch. My technique has always been a very small patch with the sutures actually taken into the orifices of the visceral vessels. That obviously did not prevent the formation of these problems in my patients. Now in the patients with Marfan and Ehlers-Danlos with their inherent problems, my approach to those, as well as those with aortic dissection and recurrent patch aneurysms, is to do individual grafts to the visceral vessels. Would not that be a safer technique for recurrent problems?

And finally, since Dr Williams has popularized the technique of tailoring the thoracoabdominal aorta in patients with chronic aortic dissection, have you seen an increased incidence of late aneurysm formation in that group of patients, although obviously this is not the group of patients that you included in this study?

I again congratulate the authors on an excellent paper. Over the years Dr Williams has taught us a great deal about technique in the management of aneurysm disease. Today he also teaches us the need for intense postoperative vigilance in these patients. Thank you.

Dr Alan Dardik. Thank you very much for your comments, and I especially thank your wife for letting you come here on your anniversary.

With regard to your first question, should we scan our patients postoperatively yearly, we do believe very strongly to scan our patients yearly. However, we do not start that until about the fifth year postoperatively. In fact, we are thinking of reducing that to starting on the fourth year postoperatively depending on the patient's age. We scan them every 12 months, and we usually obtain three-dimensional reconstruction.

Should we put individual grafts into our patients with Marfan syndrome? If possible, that is a very good idea. In our hands, we usually do distal aortic perfusion, and we do not do an octopus to the visceral segment, nor do we have separate perfusion of the kidneys. Therefore, to minimize our overall visceral ischemic time, we do tend to put our patients' patches in as a single patch, but we tend to minimize the area of the patch itself. In Marfan's patients, we will, for example, do a separate bypass to the celiac, to the left renal, and perhaps maybe do a very small patch to the SMA right renal as they are often very close together; if not possible, we do agree with your proposal.

Finally, we have been noticing some patients undergoing tailoring procedures having degeneration of that area in the Marfan group; however, that really was not the focus of this paper.

Unidentified Speaker. Very good paper. One question. With a 40% mortality, it begs the question, at least in my mind, what are the tips? What is the best way to approach these? How did you approach them—from the front, from the retroperitoneum, from the back, every different way? And what have you learned?

Dr Dardik. These patients were all approached in retroperitoneal fashion. Usually the incision was simply made through the old incision. There was only one patient done emergently, but all other patients were done electively and there was a small amount of scar tissue getting in and that really was not prohibitive. What we did notice is that around the visceral patch itself there was a large amount of inflammation similar to what one would notice in many difficult operations. That was tremendously difficult to dissect. In fact, we would rarely dissect it; we would often control back-bleeding with intraluminal Fogarty catheters.

Dr Paul Bloch (Portland, Me). Thank you Dr Dardik for elucidating your experience with this terrible problem. I have several questions for you. Laplace's law would state that wall tension is directly proportional to diameter, and I was wondering in your patients who did not have connective tissue disorders if you noted that this problem was more common in larger diameter grafts.

The second question is, just based on the physics of the situation, do you think there would be a benefit from using a graft that is narrower in the position that you create this patch?

Thank you.

Dr Dardik. Thank you for your questions. First, we use #26 or #28 aortic grafts most commonly and have not correlated patch expansion to the size of the graft. Second, this is an interesting proposal, but I am not sure if these grafts exist or whether they would be more difficult to use.

Dr Victor Weiss (Atlanta, Ga). We recently reviewed our experience with this same problem and were surprised to find that in the six patients who underwent surgery for this, five had COPD, four of whom had steroid-dependent COPD, and I was wondering if you had looked at this as an independent risk factor.

Dr Dardik. We looked at COPD. It was only present in two of our patients.

Dr Martin Back (Tampa, Fla). Having battled one of these cases in my young career I can attest to the difficulty in their management. I would ask you specifically, were any of these recurrent aneurysms due to pseudoaneurysm formation? That is, was there a uniform enlargement of the patch area for which your conclusion is appropriate—a small patch size initially may limit aneurysm formation—versus a pseudoaneurysm because of degeneration in the local wall that you may not be able to control by limiting initial patch size?

Dr Dardik. They were all true aneurysms. There were no pseudoaneurysms in this group. Thank you for the opportunity to present this paper.