Aneurysm sac pressure measurements after endovascular repair of abdominal aortic aneurysms

Richard A. Baum, MD,[a] **Jeffrey P. Carpenter, MD,**[b] **Constantin Cope, MD,**[a] **Michael A. Golden, MD,**[b] **Omaida C. Velazquez, MD,**[b] **David G. Neschis, MD,**[b] **Marc E. Mitchell, MD,**[b] **Clyde F. Barker, MD,**[b] and **Ronald M. Fairman, MD,**[b] *Philadelphia, Pa*

Objectives: **The goal of endovascular grafting of abdominal aortic aneurysms (AAAs) is to exclude the aneurysm sac from systemic pressure and thereby decrease the risk of rupture. Unlike conventional open surgery, branch vessels in the sac (eg, lumbar artery and inferior mesenteric artery [IMA]) are not ligated and can potentially transmit pressure. The purpose of our investigation was to evaluate the feasibility of various interventional techniques for measuring pressure within the aneurysm sac in patients who had undergone endovascular repair of AAAs.**

Methods: **Sac pressure measurements were performed in 21 patients who had undergone stent graft repair of AAAs. Seventeen of 21 patients had endoleaks demonstrated on 30-day computed tomographic (CT) scans. Access to the aneurysm sac in these patients was through direct translumbar sac puncture (5 patients), through a patent IMA accessed via the superior mesenteric artery (SMA) (9 patients), or by direct cannulation around attachment sites (3 patients). Four patients had perioperative pressure measurements obtained through catheters positioned along side of the endovascular graft at the time of its deployment. Two of these catheters were left in position for 30 hours during which time CT and conventional angiography were performed. Pressures were determined with standard arterial-line pressure transduction techniques and compared with systemic pressure in each patient.**

Results: **Elevated sac pressure was found in all patients. The sac pressure in patients with endoleaks was found to be systemic (15 patients) or near systemic (2 patients) and all had pulsatile waveforms. Elevated sac pressures were also found in patients without CT or angiographic evidence of endoleak (2 patients). Injection of the sacs in two of these patients revealed a patent lumbar artery and an IMA.**

Conclusions: **It is possible to measure pressures from within the aneurysm sac in patients with stent grafts with a variety of techniques. Patients may continue to have pressurized AAA sacs despite endovascular AAA repair. Endoleaks transmit pulsatile pressure into the aneurysm sac regardless of the type. It is possible to have systemic sac pressures without evidence of endoleaks on CT or angiography. (J Vasc Surg 2001;33:32-41.)**

Repair of abdominal aortic aneurysms (AAAs) by means of endovascular grafting is thought to protect the aneurysm sac from systemic pressure and thereby eliminate the risk of rupture. The reaction of the aneurysm sac after stent grafting, however, is unpredictable. Some aneurysms shrink, some maintain their size, and others will continue to enlarge.[1,2] Many factors including the presence or absence of endoleaks may contribute to this variable reaction. Measuring pressures from within the excluded aneurysm sac may help provide an explanation for this inconsistent response. The purpose of our investigation was to evaluate the feasibility of various interventional techniques for measuring pressure within the aneurysm sac in patients who had undergone endovascular repair of AAAs.

From the Department of Radiology[a] and the Department of Surgery,[b] University of Pennsylvania Medical Center.

Competition of interest: nil.

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Reprint requests: Richard A. Baum, MD, Section of Interventional Radiology, Department of Radiology, University of Pennsylvania Medical Center, 3400 Spruce Street, Philadelphia, PA 19104 (e-mail: baumr@rad.upenn.edu).

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METHODS

We performed a retrospective review of clinical cases. Sac pressure measurements were performed in 21 patients who had undergone stent graft repair of AAAs. Seventeen (81%) of these had endoleaks demonstrated on computed tomographic (CT) scans obtained 30 days after initial implantation (Table). Access to the aneurysm sac in these patients was through a direct translumbar sac puncture (5 patients), through a patent inferior mesenteric artery (IMA) accessed via the superior mesenteric artery (SMA) (9 patients) or by direct cannulation around attachment sites (3 patients). Pressure measurements in these 17 patients were obtained as part of endoleak embolization procedures. In these patients, pressures were sampled from within the endoleak, not from the thrombosed portion of the aneurysm sac. Endoleak pressures were recorded as "systemic" if the mean pressure fell within approximately 20% of the actual mean systemic pressure as measured through an arterial catheter or brachial sphygmomanometer. The remaining four patients (19%) had perioperative pressure measurements obtained through catheters positioned along side of the endovascular graft at the time of its deployment. All patients were enrolled in one of several ongoing stent graft clinical trials (Appendix) and signed an institutional review board–approved informed consent.

Translumbar endoleak pressures. We have recently described our technique for translumbar embolization of

Endoleak pressure measurements in 17 patients

Patient no.	*Graft type*	*Configuration*	*Leak origin*	*Pressure measured from:*	*Endoleak pressure*	*Arterial pressure wave?*
1	Talent	Monoiliac	IMA	Transarterial	Systemic	Yes
2	Talent	Monoiliac	IMA	Transarterial	Systemic	Yes
3	Talent	Bifurcated	IMA	Transarterial	Systemic	Yes
4	Talent	Bifurcated	IMA	Transarterial	½ systemic	Yes
5	EVT	Bifurcated	PA	PA	Systemic	Yes
6	EVT	Bifurcated	IMA	Transarterial	Systemic	Yes
7	Talent	Monoiliac	IMA	Translumbar	Systemic	Yes
8	Talent	Bifurcated	IMA	Transarterial	½ systemic	Yes
9	EVT	Bifurcated	IMA	Transarterial	Systemic	Yes
10	Talent	Monoiliac	IMA	Translumbar	Systemic	Yes
11	EVT	Bifurcated	IMA	Translumbar	Systemic	Yes
12	Talent	Bifurcated	Lumbar	Translumbar	Systemic	Yes
13	Talent	Bifurcated	Lumbar	Translumbar	Systemic	Yes
14	Talent	Bifurcated	DA	DA	Systemic	Yes
15	Talent	Bifurcated	PA	PA	Systemic	Yes
16	Talent	Monoiliac	IMA	Transarterial	Systemic	Yes
17	EVT	Bifurcated	IMA	Transarterial	Systemic	Yes

DA, Distal attachment site; *IMA,* inferior mesenteric artery; *PA,* proximal attachment site.

type 2 endoleaks.[3] Direct translumbar endoleak punctures were obtained with the patient prone on the fluoroscopy table and under conscious sedation and local anesthesia. The location of the leak was identified on CT and referenced to bony landmarks and to the stent graft radiopaque markers (Fig 1). A 19-gauge 20-cm needle with a 5F Teflon sheath (Boston Scientific Corp, Watertown, Mass) was advanced by means of fluoroscopic guidance through the back at the level of the leak approximately 5 cm from the midline. Once the aneurysm sac was entered, the inner needle was removed, and the Teflon sheath was advanced either alone or over a coaxial guidewire to reach the site of leakage. Correct positioning within the endoleak was signaled by a pulsatile return of blood through the 5F catheter. Endoleak angiography was performed with an injection of 10 to 20 mL of nonionic contrast (Omnipaque 300; Nycomed, Inc, Princeton, NJ) to confirm the leak's origin. Pressures were measured from within in the leak with a pressure transducer (Mamic Perceptor Morse Manifold, Medium Pressure; Boston Scientific Corporation, NAMIC Technology Center, Glen Falls, NY) placed at the level of the abdominal aorta and compared with brachial sphygmomanometer pressure readings. Endoleaks were then embolized to stasis with microcoils.[3] Postembolization pressures were also obtained in these five patients from within the endoleak at the completion of the procedure.

Transarterial pressure measurements. Cannulation of the IMA in stent graft patients has previously been described.[4-6] With this technique, the IMA (and the endoleak) can be entered by means of a coaxial microcatheter that travels a circuitous route from the SMA and middle colic artery. In our series, aneurysm sac pressures were obtained with a 3F 150-cm microcatheter (Fast Tracker 18; Boston Scientific), which was positioned within the endoleak. To achieve this, we placed a 4F or 5F catheter into the proximal SMA through which a microcatheter was used to cannulate the middle colic artery and IMA. The aneurysm sac was then entered in a retrograde fashion, passing through the IMA. Intraendoleak pressure measurements were recorded and compared with systemic arterial pressure acquired simultaneously from the side port of a 6F arterial sheath (Fig 2). Endoleaks were then embolized to stasis with microcoils.[4]

Attachment site pressure measurements. Direct cannulation of the aneurysm sac around attachment sites was performed in the three patients who had type 1 endoleaks with 4F hydrophilic catheters (Glidecath; Boston Scientific). This was accomplished from the right common femoral artery in two patients and the left brachial artery in one patient.

Intraoperative and perioperative pressure measurements. Intraoperative and perioperative pressure measurements were obtained in the aneurysm sacs of four patients without evidence of endoleaks. In the first two patients, microcatheters (Fast Tracker 18; Boston Scientific) were positioned transarterially into the aneurysm sac during the stent graft insertion procedure. Because of durability issues, larger (4F) straight catheters (Glidecath; Boston Scientific) were used in the final two patients. These catheters were left in position for approximately 30 hours, during which time CT and conventional angiography were performed. Direct puncture of the femoral artery (through the skin and subcutaneous tissue) was performed with the Seldinger technique on the "contralateral side" to introduce the catheters. In the three patients with modular bifurcated systems, this was done before the introduction and deployment of the contralateral limb. In the one patient with a monoiliac graft, the pressure-measuring catheter was introduced in the same fashion before contralateral common iliac artery embolization. Patients were followed up in an intensive care unit setting, and continu-

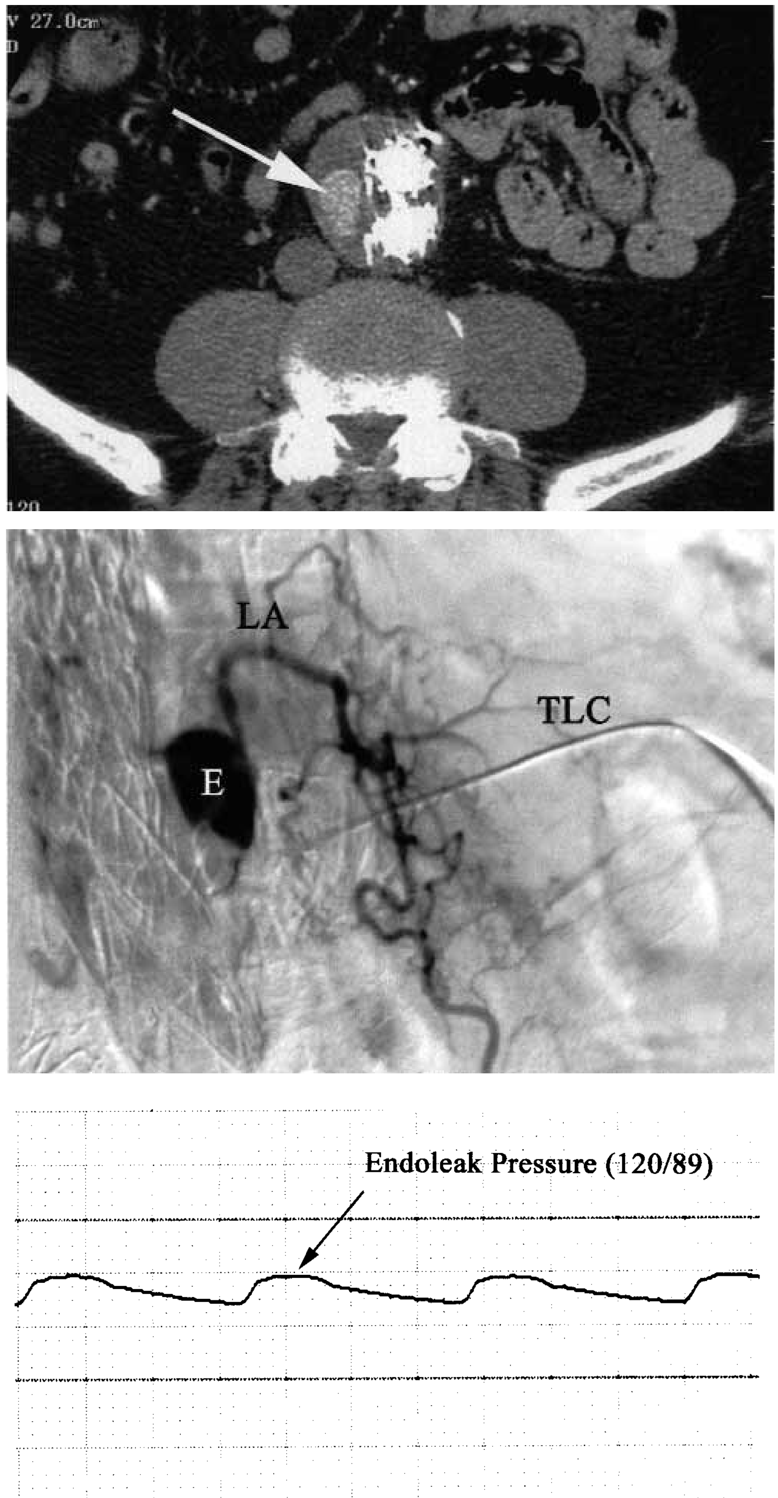

Fig 1. Systemic pressure in a lumbar endoleak through translumbar puncture. **A,** CT angiography in lower abdomen shows endoleak (*arrow*) in right lateral portion of aneurysm sac. **B,** Direct translumbar catheterization (*TLC*) and angiography of the endoleak (*E*) show several draining lumbar arteries (*LA*). **C,** Systemic pressure is measured from within lumbar endoleak.

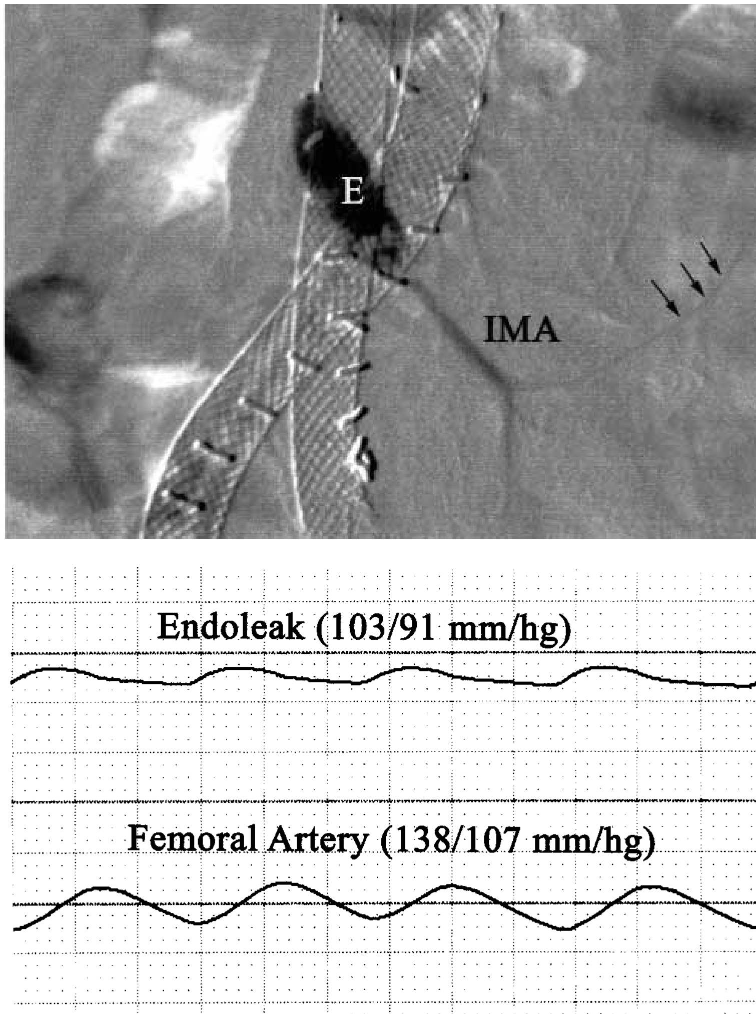

Fig 2. Systemic pressure in IMA endoleak. **A,** A transarterial catheter (*arrow*) is placed through the IMA and into an endoleak (*E*) via the SMA. **B,** Systemic pressure is measured from within IMA endoleak. *IMA,* Inferior mesenteric artery.

ous pressure monitoring was performed through the intrasac catheter and compared with systemic arterial pressure acquired simultaneously through a radial arterial line. Prophylactic antibiotics (cefazolin, 1 g; American Pharmaceutical Partners, Inc, Los Angeles, Calif) were given intravenously at the time of the procedure and continued while the catheter was in place.

Two patients with indwelling sac catheters underwent CT scans at 30 hours, which were followed by contrast angiograms performed with a 10-cc injection of iodinated contrast (Omnipaque 300; Nycomed, Inc) into the aneurysm sac. In one patient, the catheter was also withdrawn from the sac into the native external iliac artery and was then advanced into the lumen of the stent graft where a pigtail aortogram was performed.

RESULTS

Intra-aneurysm sac pressure measurements were successfully acquired in each of the 21 patients studied. There were no failed sac pressure measurement attempts. Elevated pressures and arterial waveforms were found in every one of the 17 patients with endoleaks, 15 (88%) of which were systemic. The remaining two patients (12%) had pressures that were one-half systemic (Table). The origin of the endoleaks was from the IMA in 12 patients, the lumbar arteries in 2 patients, the proximal attachment site in 2 patients, and the distal attachment site in 1 patient. There was no distinction between the type and size of the endoleak and the pressure measurement obtained.

Translumbar access to the aneurysm sac and endoleaks was achieved successfully in all five patients studied. There were no complications related to the procedure, and all patients were discharged home the following morning. Preembolization endoleak pressures were systemic with arterial waveforms in all five patients and fell to between 20 and 30 mm Hg after treatment (Fig 3).

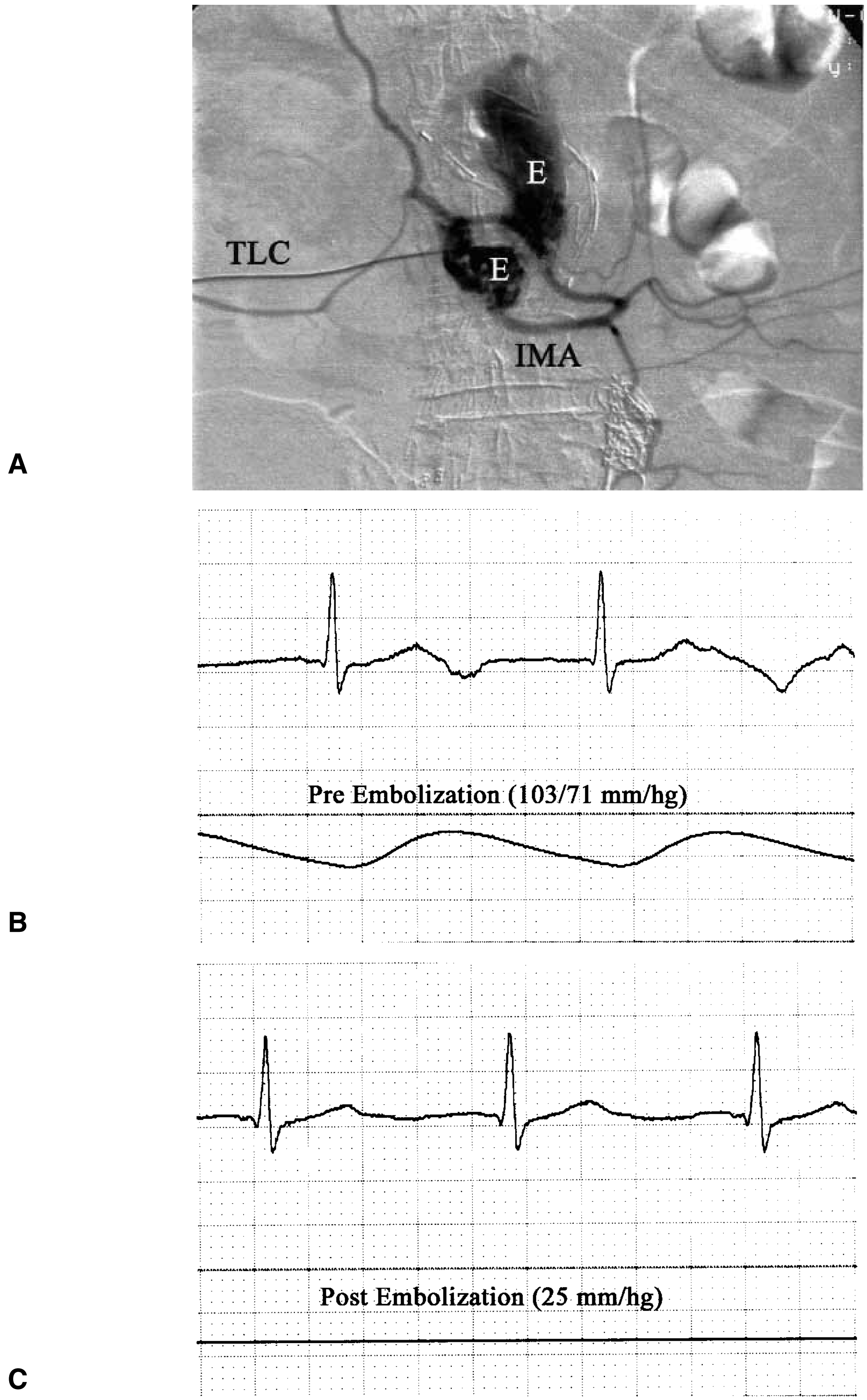

Fig 3. Translumbar embolization of a lumbar endoleak. **A,** Translumbar endoleak angiogram through a 5F catheter (*TLC*) in the anteroposterior projection. **B,** Systemic pressure is measured from within IMA endoleak. **C,** The endoleak pressure falls to 25 mm Hg after translumbar embolization. *E,* Endoleak; *IMA,* inferior mesenteric artery.

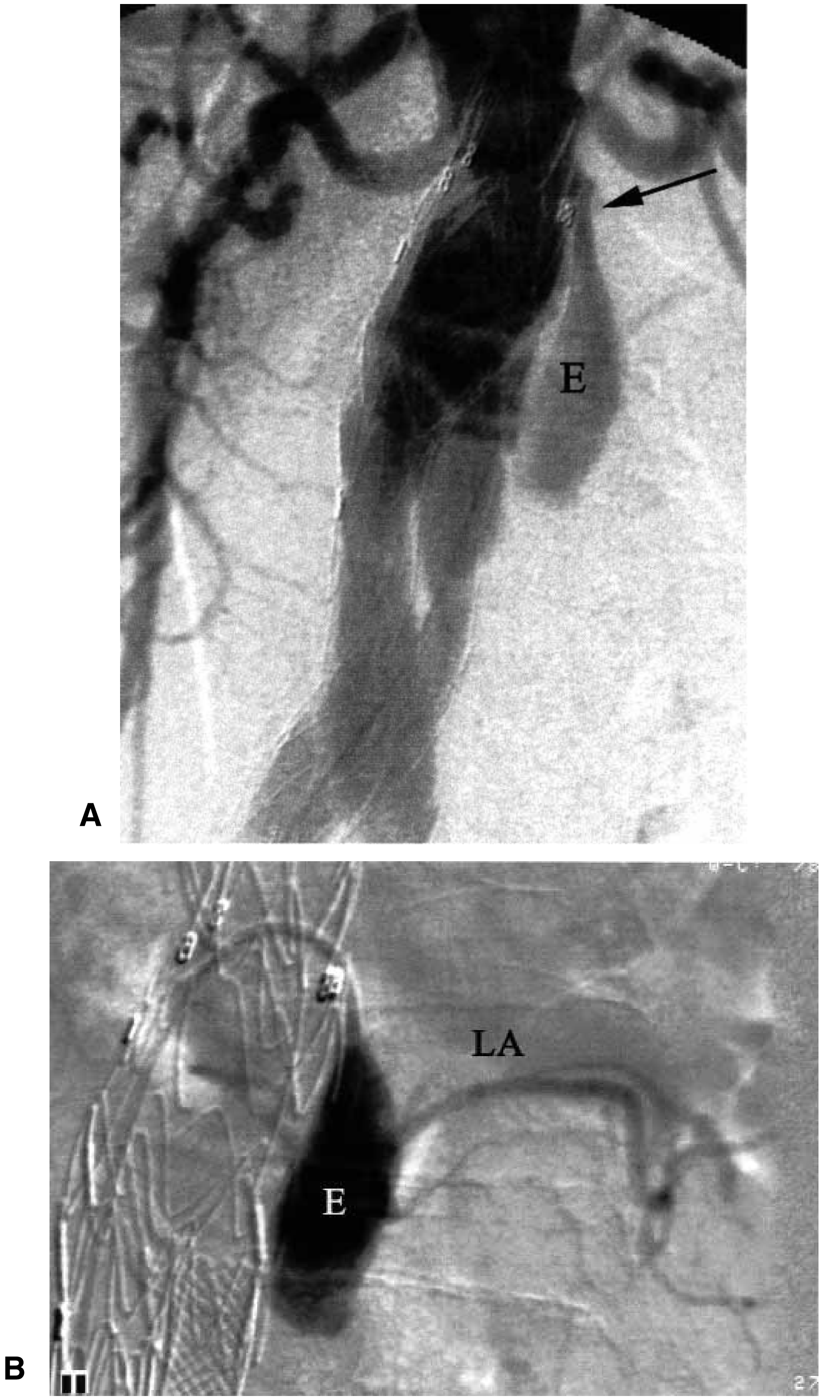

Fig 4. Type 1 endoleak angiogram. **A,** Contrast angiography in the anteroposterior projection shows type 1 endoleak (*E*). **B,** Angiogram from within endoleak shows a draining lumbar artery (*LA*).

Transarterial pressure measurements were successfully obtained through a microcatheter in nine patients with IMA endoleaks and were compared with femoral arterial pressure. The endoleak pressures were systemic with an arterial pressure wave in seven (78%) of nine patients (Fig 2). Two patients had pressure that was one-half systemic with arterial waveforms.

Intraendoleak pressures were also successfully measured in three patients with attachment site leaks and compared with femoral arterial pressure. The endoleaks contained sys-

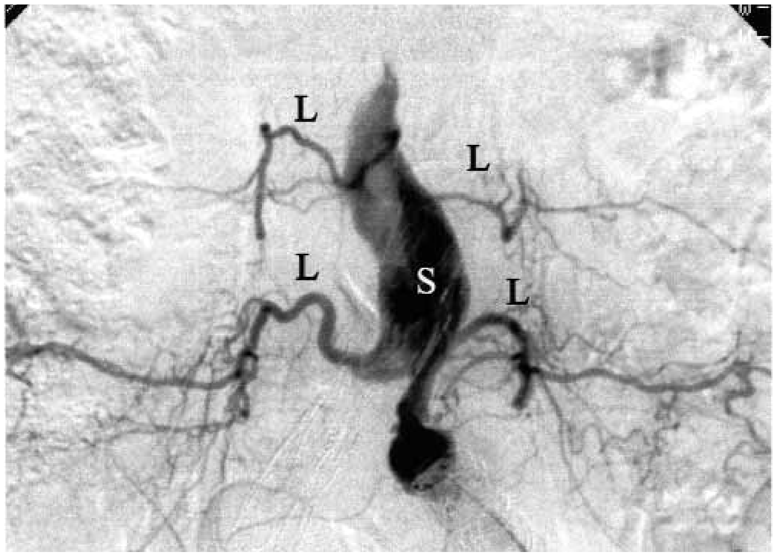

Fig 5. Intra-aneurysm sac injection after endovascular repair of AAA *(L)*. Contast injection through a 5F intrasac catheter 30 hours after uniiliac stent graft repair of AAA shows multiple patent lumbar arteries. Systemic pressure was measured from within the sac *(S)*. The patient had a negative result from CT scan 30 minutes before angiogram.

temic pressure with arterial waveforms as measured with a 5F catheter positioned from within the leak (Fig 4).

Elevated sac pressure was also found in the four patients without CT or angiographic evidence of endoleak. Initially, the mean and pulse pressures fell in three patients as soon as the aneurysm was excluded. In the fourth patient (with a monoiliac graft), the pressure did not fall after aneurysm exclusion and contralateral common iliac artery embolization. The 3F microcatheters that were placed in two of these patients were not durable. The first did not function after the patient was transferred to the recovery room, and the second failed after the patient sat up in bed 3 hours after the procedure. Both catheters were removed at bedside without complication. Placement of the 4F catheters proved sturdier with each functioning well until they were removed 30 hours after placement. The sac pressure in these two patients continued to rise during the perioperative period and became systemic at approximately 24 hours. Injection of the sacs in these two patients revealed a patent lumbar artery and an IMA despite negative results from CT and conventional angiograms (Fig 5).

DISCUSSION

The response of an AAA to endovascular grafting is unpredictable.[2,7-9] Even if an aneurysm is successfully excluded, there is no guarantee that the sac will shrink. Guidant/EVT reports that only 68.5% of patients from its US clinical trial had shrinking aneurysms at 2 years.[10] The implication of an endograft patient with a nonshrinking aneurysm is a topic of great debate.

Intraendoleak pressure measurements. We are unaware of other reports of in vivo pressure measurements taken from within endoleaks. Many have suggested that endoleaks pressurize the aneurysm sac and put the patient at risk for rupture.[11] Clever animal and human models have supported this assertion.[12-14] Our finding of systemic pressure and arterial waveforms from within endoleaks validates this principle. All endoleaks in our study had arterial waveforms and elevated pressure with 15 (88%) of 17 being systemic. The significance of the two patients with endoleaks who had one-half systemic pressure is uncertain. It is possible that these endoleaks represent less well-developed IMA–lumbar artery circuits. It is also possible that the severe tortuosity kinked the 3F microcatheter and led to inaccurate pressure transduction because this finding was not seen when endoleaks were entered with 5F translumbar or transarterial catheters.

The most straightforward, robust, and our preferred method for measuring aneurysm sac pressures was by direct translumbar puncture. This easily enabled us to position large (5F) catheters directly within endoleaks. Not only were pressures able to be measured directly, but this technique also allowed us to perform endoleak angiography and assess the results of embolization. In our series, all five translumbar patients had postembolization pressures of less than 30 mm Hg. Although this represents a dramatic reduction, we were never able to reduce the pressure in the leak to less than 20 mg Hg despite packing the leaks tightly with coils. Perhaps this residual pressure represents transmitted pressure from surrounding structures and a "diaphragm effect" the pulsatile graft has on the surrounding aneurysm sac.

When to treat endoleaks. When to intervene in a patient with an endoleak is a complex and controversial question. Some think that it is important to treat attachment site leaks early while acceptable to wait for collateral leaks to thrombose spontaneously.[15,16] Because we could demonstrate systemic pressure in both attachment and collateral leaks regardless of their size or type (IMA or lumbar artery), we have adopted a more aggressive approach. At our institution, if a patient demonstrates a leak on the 30-day CT scan, it is treated. We realize that some collateral endoleaks will spontaneously thrombose; however, until that occurs we have shown that there is systemic arterial pressure within the aneurysm sac. It is unknown whether an embolized endoleak differs in physiology or long-term outcome from a spontaneously thrombosed leak.[17] We are, however, encouraged that we were able to decrease endoleak pressures after embolization to less than 30 mm Hg in all five translumbar cases (Fig 3). It would be interesting to measure sac pressures in patients who have undergone either treatment or spontaneous closure of their endoleaks.

Intrasac pressure measurements. The concept of cannulating the backside of a stent graft to measure pressures is not a new one.[18] In 1997, Chuter et al[19] placed catheters alongside eight aorto-uniiliac stent grafts.[19] They found a significant decrease in both mean and pulse pressures when compared with radial artery pressure. Our limited experience in four patients using essentially the same technique confirms their findings. Immediately after aneurysm exclusion there was a reduction in mean and pulse pressures in the sac of each bifurcated patient (3 patients). Unlike Chuter et al, however, we left the catheters in position (in 2 patients) during the perioperative period and found that mean and pulse pressure continued to rise the longer the catheter was left in place; at times, it exceeded the radial artery mean pressure. The exact significance of this finding is uncertain, but perhaps the reversal of branch vessel flow and the establishment of ingress and egress channels through the clotted sac take time to develop. It would be unwise to make any conclusions on the basis of only two patients.

A potential limitation of this technique is the possibility of creating an attachment site endoleak with the pressure-measuring catheter. However, we think that this is unlikely to occur because of the small size of the catheter and the length the catheter travels behind the supported stent graft limbs.

Endotension. The concept of pressurized sacs and occult endoleaks that are not visualized with current imaging has recently been introduced, and the term *endotension* has been applied.[20,21] Our series shows that this concept is possible because two patients had systemic pressures within the aneurysm sac 30 hours after endograft repair without CT or angiographic evidence of endoleaks (Fig 5). Our findings also demonstrate the potential limitations of CT angiography in visualizing all endoleaks.

Limitations. Our investigation is limited in scope because of its small sample size and retrospective design. A prospective longitudinal study in which intrasac pressures are measured in patients with and without endoleaks would be useful. This would be possible by modifying our existing translumbar embolization technique[3] to use a 21-gauge needle (rather than a 5F catheter). Pressure measurements could be obtained every 6 months for the life of the graft or until the aneurysm sac disappeared. This procedure could also be used to investigate aneurysm sacs in patients whose aneurysms have failed to shrink despite the absence of endoleaks on CT angiography. Performing translumbar intrasac angiography in these patients could determine the etiology of occult endoleaks.

Another potential limitation is the lack of true sac pressure measurements in the endoleak group. In these patients, pressures were obtained from the endoleak itself, which may be different from the pressure in the surrounding thrombus-filled sac. It would be interesting to measure pressures from within the thrombus-filled sac and endoleak simultaneously before, during, and after endoleak embolization.

Summary. In conclusion, our feasibility study shows that it is possible to measure pressures from within the aneurysm sac in patients with stent grafts with a variety of techniques. By doing this we have made several observations:

1. Patients may continue to have pressurized AAA sacs despite endovascular AAA repair.
2. Endoleaks transmit pulsatile pressure into the aneurysm sac regardless of type, and in most cases this pressure is systemic.
3. It is possible to have systemic sac pressures without evidence of endoleaks on CT or angiography.

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APPENDIX

Clinical trials

1. A phase II investigation of the TALENT endoluminal spring stent-graft system for the treatment of subrenal abdominal aortic aneurysms in patients who are not candidates for standard surgical intervention.
2. A phase II investigation of the TALENT endoluminal spring stent-graft system for the treatment of subrenal abdominal aortic aneurysms in patients who are candidates for standard surgical intervention.
3. Use of the TALENT endoluminal spring stent-graft system in high–surgical risk patients with abdominal aortic aneurysm—emergency/compassionate use protocol.
4. A phase II clinical study of the aortoiliac EGS system as compared with the standard surgical procedure in the treatment of abdominal aortic aneurysms.
5. A phase III clinical study of the safety and efficacy of EVT Ancure tube and bifurcated systems.

DISCUSSION

Dr Sachinder S. Hans (Warren, Mich). I have one question and one observation. The observation is that we measured the aneurysm sac pressure in 21 patients during open abdominal aneurysm resection by proximal clamping of the aortic neck and distal clamping of the iliac arteries, and we found out that the aneurysm sac pressure was slightly less than half of the mean systemic blood pressure. Obviously, we always took the ratio of the aneurysm sac pressure to the mean blood pressure of the patient, and we calculated that ratio and it was slightly less than half. Not surprisingly, it directly correlated with the number of actively bleeding lumbar arteries. It had no relationship to the size of the aneurysm or the presence of the thrombus in the aneurysm.

I have one question regarding your study: you had four or five different techniques of measuring the aneurysm sac pressure. Are these techniques equally sensitive? Have you tested them in the animal or the lab model?

And the follow-up question I have is, that these two aneurysm sac pressures, the one that you describe and the one we have measured in the aneurysm sac during open aneurysm resection, are not the same. It appears that aneurysm sac pressure even increases in the follow-up period after the implantation of the device.

Thank you very much, Dr Baum, for an excellent presentation.

Dr Richard A. Baum. In terms of our techniques, no, we have not tested them in the laboratory or in an animal model. You have to remember that this particular study was a retrospective look at clinical cases. The pressure measurements were obtained during treatment for endoleaks, and as our techniques evolved over time, we measured pressures in different ways. Our algorithm now is certainly a lot different than it was 2 years ago.

Your second point is correct. In our limited experience we have seen aneurysm sac pressures during the first 24 hours after insertion.

Dr John D. Edwards (Cincinnati, Ohio). What a beautiful paper and beautiful demonstration. I'll paraphrase Dr Green; I hope I do it well. At a meeting in Boston I heard him speak at a couple of years ago, he asked if we can replace an effective treatment that essentially cures patients of their disease with a prophylactic procedure? He said it more eloquently, but I think you sort of showed why that was. I hope that was okay, Dr Green.

Now to my question. This should surprise the radiologists who would pretend to be aneurysm experts and should maybe educate the cardiologists, but we've all been in a situation where we've fixed the aneurysm. There weren't any lumbar back bleeders, but we were pretty sure our resident must have missed a couple. We didn't see any, and after reperfusing direct flow to the hypogastrics and the externals and all those collaterals, they started to bleed after the fact, and maybe even sometimes, unfortunately, brought us back to the operating room in the middle of the night. So this probably shouldn't be surprising.

Now, to my question. Dr Parodi, who stays ahead of this curve and amazes me still, for 2 years has been talking about clipping laparoscopic approaches. Is that what you're going to do at HUP now because of all this, or are you going to change your approach and combine a laparoscopic with an endoluminal approach?

Dr Baum. Thank you for your kind comments. With regard to your question, yes, I was surprised by our findings, but I am a radiologist.

Dr Edwards. A radiologist at a surgical meeting, though.

Dr Baum. There you go.

We have not attempted laparoscopic repair of collateral endoleaks at our hospital largely because we have been able to treat them using transarterial or translumbar techniques.

Dr Berguer. Dr Green, do you want to make a correction?

Dr Green. John, it was palliative. We've taken a cure and given a palliation.

Dr Edwards. What did I say? Prophylactic. You know, you've got to learn English.

May I rise to ask one more question?

Dr Baum. Sure.

Dr Edwards. What's the difference between thrombus that God and the aneurysm sac put there and thrombus that you put there when you embolize a vessel that's back bleeding? Why is the one protective and the other is not?

Dr Baum. I think what we're doing by embolization is putting up a dam or blocking flow through the aneurysm sac. And you're absolutely right, I'm not certain that my embolization techniques are any more or less effective than just a clot in the aneurysm sac. I think it would be very interesting to measure pressures within aneurysm sacs in both patients with and without endoleaks to learn if there is a difference.

Dr Takao Ohki (New York, NY). I have two questions. One is a very quick one.

At what period did you intervene on these 17 endoleaks? That's question one. Can I have the answer for that first?

Dr Baum. We treated our endoleaks from 30 days to 6 months after stent graft deployment.

Dr Ohki. So I think you are intervening on these type 2 endoleaks a bit too early. If you could wait a bit longer, they might thrombose spontaneously. This is my number one comment.

Number two is regarding your comment about no matter what the size, where they came from, they all exerted systemic pressure. I think that observation is correct, but the message that observation sends out I think needs some careful interpretation. You showed one type 1 endoleak from the proximal attachment site, and you showed several type 2 from the lumbar or the IMA. In terms of the pressure measurements, they were the same. But in terms of the treatment options and the outcome, they are totally different. If you embolize the type 2 systemic pressure leaks, they are fine. But if you try to do the same thing with a type 1, they are basically untreated. And I think you have to differentiate the source of the leak regardless of the fact that they were the same pressure.

Dr Baum. I think that's conventional wisdom, but I'm not sure it's correct. From our preliminary work we have shown that there is little difference in sac pressure in patients with type 1 and type 2 endoleaks. In terms of why we intervene so soon, you have to remember, we now have a straightforward procedure (translumbar endoleak embolization), which can be done in these patients. You can wait for the endoleaks to thrombose on their own, and I realize if you look at the data and other people's experience, a lot of these type 2 endoleaks will seal. But I think the thing you can learn from our experience is that until they do seal, they have systemic pressure. And if you have an aneurysm with a systemic pressure and you have an easy way to fix it, why wait? You've done all of the detail work to measure it, to design the graft, to put the graft in. Why not, with very little morbidity, just finish the procedure? Do the best you can.

Dr Ohki. Then why not use embolization agent at the time of the procedure?

Dr Baum. You're exactly right: embolization of the aneurysm sac after stent graft deployment could prevent type 2 leaks from forming.

Dr Ohki. And we do have a paper at the upcoming European vascular society proving that not all endoleaks are the same after thrombosis.

Dr Mark A. Mattos (Springfield, Ill). One just sort of research, philosophical question. Dr Baum, do you think there is a role for the possibility that when you place the graft primarily or possibly putting either thrombin or an acrylic compound to seal any of those endoleaks by leaving a catheter in one of the limbs and, as you seal that ipsilateral limb, pulling it out, therefore avoiding systemic injection of that, but certainly sealing the aneurysm at the time of surgery?

Dr Baum. That's obviously the answer to all of this, some sort of insulation material, if you will, foam or something that goes in at the time of stent graft deployment. I think thrombin is probably not the right choice because its effects are at the capillary level, but something that sticks in the arteriole level. You're absolutely right; I think that is an obvious solution.

Dr Geoffrey H. White (Sydney, Australia). I would also like to congratulate you for a superb paper and for confirming what we suspected about pressure in these type 2 endoleaks. We know the effects of type 2 endoleak and type 1 are markedly different, presumably because their pressure isn't transmitted as readily through the thrombus or because the flow is lower. I'm wondering if you had the opportunity to measure pressure within the thrombus adjacent to the endoleak cavity and also whether you found any difference between using coils alone or coils plus adjuncts, such as fibrin glues?

Dr Baum. Thank you for your comments. Yes, we have been able to measure clot pressure translumbar embolization. You don't always get directly into the endoleak at the time of translumbar puncture. Sometimes you have to meander around the sac a little bit to find the actual leak site. In these patients we measured systemic pressures from within the sac thrombus itself.

Again, what I think really needs to be done is to apply our translumbar technique, to measure pressures before or after different treatments and in patients without endoleaks. I mean we don't know what the pressure is in an aneurysm that is shrinking. Maybe that has systemic pressure.

Dr White. The pressure in the thrombus next to the cavity, is that elevated as well?

Dr Baum. Yes, it is, before we embolize the leak, and it falls when the leak is treated with embolization.

Dr Juan C. Parodi (Buenos Aires, Argentina). I want to congratulate you for your superb presentation. I think this is a very important issue. As a matter of fact, I think this is the problem we still have to solve. The other is neck dilatation, which I don't believe is an issue anymore, since we are learning that placing the proximal end of the endograft close to the renal arteries or even crossing them provides secure fixation and sealing, and at last the industry is going to take care of mechanical failures of devices that we have seen with several systems.

We tried many years ago to occlude the sac at the same time we were placing the endograft. And even doing angioscopy of the sac, it was not very easy at all to identify and occlude the branches. We ended up injecting Spongostan free in the sac. And I am aware of a study, long term now, from Nottingham, they injected Spongostan in the sac during the procedure having superb results. They had just 4% of type 2 endoleaks after 3 years in patients that had more than 4 lumbars to start with. So they were able to occlude 96% of them during the procedure. They are now using Ivalon instead of Spongostan. Dr Hopkinson has many more cases than we have. We believe that this is going to be a good approach.

My question is: Are you planning to start doing this during the procedure to prevent these type 2 endoleaks?

Dr Baum. Thank you for your remarks and insightful comments. We have not tried to use materials that would help thrombose branch vessels at the time of stent graft deployment. In addition to regulatory issues, we have not identified the ideal embolic agent.