Morphologic Changes and Outcome Following Endovascular Abdominal Aortic Aneurysm Repair as a Function of Aneurysm Size

Frank R. Arko, MD; Konstantinos A. Filis, MD; Bradley B. Hill, MD; Thomas J. Fogarty, MD; Christopher K. Zarins, MD

Hypothesis: Small infrarenal abdominal aortic aneurysms have a more favorable clinical and morphologic outcome compared with medium and large abdominal aortic aneurysms following endovascular aneurysm repair (EVAR).


Setting: A tertiary care academic health center.

Patients: Patients were grouped according to aneurysm size: small (<50 mm), medium (50-60 mm), and large (>60 mm).

Interventions: Primary EVAR and secondary procedures to secure fixation of the stent graft and surgical conversions.

Main Outcome Measures: Aneurysm diameter, endoleaks, and long-term morphologic changes were analyzed postoperatively with 3-dimensional reconstructions of computed tomographic angiograms.

Results: Groups were similar in age, comorbidities, and follow-up (mean±SD, 32.1±11.8 months). There were 30 small aneurysms, 92 medium aneurysms, and 84 large aneurysms, with a mean size of 45.1±3.7 mm, 53.8±3.1 mm, and 66.1±6.8 mm, respectively (P<.01). There was no significant difference in proximal neck or iliac artery diameter among the 3 groups. The proximal aortic neck length (28.1±11.6 mm [small]; 23.9±11.3 mm [medium]; and 22.1±11.6 mm [large]; P<.05) was significantly shorter in large aneurysms. Furthermore, there was a significant increase (6% [small]; 15% [medium]; and 21% [large]; P<.05) in angulated necks in large aneurysms. Following treatment, aneurysm diameter remained stable in most patients (83% [small]; 82% [medium]; and 83% [large], with a mean decrease of 2.0±6.5 mm, 2.1±6.1 mm, and 3.7±7.7 mm in each group, respectively (P=.45). There was no difference in the incidence of endoleaks, aneurysm contraction, or aneurysm expansion based on preoperative aneurysm diameter. Secondary procedures were performed in 5 (20%) of 25, 9 (5.2%) of 170, and 5 (36%) of 11 aneurysms that contracted, remained stable, or expanded, respectively, following EVAR (P<.05).

Conclusions: There is a 15% increase in neck angulation and a 27% decrease in neck length in large compared with small infrarenal abdominal aortic aneurysms, with no difference in outcome. Aneurysms that are stable following EVAR have a significantly lower incidence of requiring secondary procedures.

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The purpose of this study was to compare the morphologic changes and outcomes of small, medium, and large aneurysms following EVAR. We followed up the morphologic characteristics of the aneurysms, noting changes in diameter, to determine if aneurysm shrinkage and endoleaks are important outcome measures in the prevention of aneurysm rupture and aneurysm-related death.

### METHODS

Between October 1996 and June 2002, we treated 206 patients with infrarenal abdominal aortic aneurysm with the AneuRx stent graft (Medtronic, Santa Rosa, Calif). All patients were entered prospectively into a vascular database. Patient age, sex, and comorbidities were recorded. Preoperative proximal aortic neck length, diameter, infrarenal neck angulation, aneurysm diameter, and iliac artery diameters were determined from 3-dimensional reconstructions of computed tomographic angiograms (CTAs). Diameter measurements were obtained by measuring from outer wall to outer wall. Length measurements were determined from median center line pathways.

Endovascular aneurysm repair was offered to patients who had a 10-mm infrarenal neck length, a neck diameter less than or equal to 26 mm, and neck angulation of less than 60°. Infrarenal abdominal aortic aneurysms were divided into 3 groups based on diameter. Small aneurysms were classified as less than 50 mm, medium, between 50 and 60 mm, and large, greater than 60 mm. The preoperative imaging study was used to determine the preoperative aneurysm characteristics. However, changes in aneurysm diameter were determined by comparing the initial postoperative scan with subsequent postoperative scans. Patients with abdominal aortic aneurysms less than 55 mm were offered treatment only if they were symptomatic, were women, or if there was a greater than 5-mm increase on follow-up imaging at 6-month intervals.

Percutaneous, femoral, or iliac artery access was used as appropriate in each patient, with general or epidural anesthesia. Graft size was based on 10% to 20% oversizing of the proximal aortic neck diameter. All grafts were bifurcated and placed infrarenally and brought into the common iliac arteries. In patients with common iliac arteries larger than 16 mm in diameter, a bell-bottom technique was used to secure fixation and ensure a seal distally.

Patient surveillance consisted of clinical examination, duplex ultrasound, abdominal radiographs, and CTA or magnetic resonance angiography prior to discharge, at 1, 6, and 12 months, and then yearly. Aneurysm size, presence and type of endoleak, and secure fixation were documented on each return visit. Increasing aneurysm diameter was considered to be greater than or equal to 5 mm from the initial postoperative CTA finding. Decreasing aneurysm diameter was considered to be greater than or equal to 10 mm from the initial postoperative CTA.

Secondary procedures were documented and performed in patients with type I endoleaks, type II endoleaks with aneurysm enlargement, and in patients with poor proximal and/or distal fixation. Secondary procedures included placement of proximal and/or distal extender cuffs to secure fixation and surgical conversion.

Results are presented as mean ± SD. Differences among groups were analyzed with an analysis of variance for 3 independent variables. A P value less than .05 is considered significant.

### RESULTS

There was no difference in age (72.3±6.8, 73.6±8.3, and 73.9±8.2 years) or number of comorbidities (2.1±1.3, 1.9±1.5, and 2.2±1.3) among small, medium, or large aneurysms, respectively (P=.78). The mean follow-up was 32.1±11.8 months (range, 3-55 months), with no difference among groups. Mortality and morbidity were 1 (0.4%) of 206 and 23 (11.3%) of 206, respectively. Overall, the aneurysm-related death rate (mortality with all primary and secondary procedures) was 1 (0.4%) in 206.

The mean aneurysm size was 45.1±3.7 mm (range, 40-49 mm) for small; 53.8±3.1 mm (range, 50-59 mm) for medium; and 66.1±6.8 mm (range, 60-100 mm) for large aneurysms (P<.01). There was no difference among the neck diameters in the 3 groups (22.0±1.9 mm [range, 20-26 mm]; 22.3±2.1 mm [range, 20-26 mm]; and 22.3±2.3 mm [range, 19-26 mm]; P=.84). Smaller aneurysms had a significantly longer neck length compared with larger aneurysms (28.1±1.6 mm [range, 10-56 mm]; 23.9±1.3 mm [range, 11-50 mm]; and 22.1±1.6 mm [range, 10-38 mm]; P<.05). Furthermore, the percentage of angulated necks increased significantly with increasing aneurysm size (2 [6%] of 30, 14 [15%] of 92, and 18 [21%] of 84; P<.05). There was no difference in preoperative iliac artery diameter among groups (12.9±1.4 mm [range, 10-16 mm]; 13.1±1.3 mm [range, 11-18 mm]; and 13.3±1.2 mm [range, 11-18 mm]; P=.53) (Table 1).

With a mean follow-up of 32.1±11.8 months, there was a mean decrease in aneurysm diameter of −2.6±0.6 mm (range, −26 to 15 mm). However, there was no significant difference in aneurysm diameter changes among small, medium, and large aneurysms (−2.0±0.5 mm, −2.1±0.1 mm, and −3.7±0.7 mm, respectively; P=.59). Most aneurysms in each group remained stable (30 [83%] of 30; 75 [82%] of 92; and 70 [83%] of 84; P=.45) after treatment. Furthermore, there was no significant difference in aneurysm shrinkage or expansion based on the

<table>
<thead>
<tr>
<th>Value</th>
<th>P Value</th>
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<tbody>
<tr>
<td>1 (0.4%) of 206</td>
<td>1 (0.4%) of 206</td>
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</tbody>
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### Table 1. Preoperative Characteristics of Small, Medium, and Large Abdominal Aortic Aneurysms Prior to Endovascular Aneurysm Repair

<table>
<thead>
<tr>
<th>Mean ± SD</th>
<th>Small (n = 30)</th>
<th>Medium (n = 92)</th>
<th>Large (n = 84)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aneurysm size, mm</td>
<td>45.1 ± 3.7</td>
<td>53.8 ± 3.1</td>
<td>66.1 ± 6.8</td>
</tr>
<tr>
<td>Neck diameter, mm</td>
<td>22.0 ± 1.9</td>
<td>22.3 ± 2.1</td>
<td>22.3 ± 2.3</td>
</tr>
<tr>
<td>Neck length, mm</td>
<td>28.1 ± 11.6</td>
<td>23.9 ± 11.3</td>
<td>22.1 ± 11.6</td>
</tr>
<tr>
<td>Neck angulation (&gt;45°), No. (%)</td>
<td>2 (6)</td>
<td>14 (15)</td>
<td>18 (21)</td>
</tr>
<tr>
<td>Iliac diameter, mm</td>
<td>12.9 ± 1.4</td>
<td>13.1 ± 1.3</td>
<td>13.3 ± 1.2</td>
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preoperative aneurysm diameter (Table 2). The number of endoleaks following treatment was also not different among groups (4 [13%] of 30; 20 [22%] of 92; and 16 [19%] of 84) (*P* = .41).

Late secondary procedures were performed in 19 (9.2%) of 206 patients, and 3 (1.4%) of 206 required late surgical conversions. There were no deaths associated with any secondary procedures or surgical conversions. All 3 patients who underwent elective surgical conversion were successfully treated without complications. The aneurysm in the first patient had a 30-mm neck on CTA and a 26-mm neck on intravascular ultrasound, with an overall neck length of 10 mm. He had a persistent type I endoleak following EVAR, without an increase in aneurysm diameter at 18 months. The second patient also had a short length (10 mm), reversed funnel (diameter, 26-28 mm) proximal neck. He had a new type I endoleak after a previous proximal extender cuff had been placed for aneurysm expansion (5 mm). An uneventful surgical conversion was performed 24 months after the initial stent-graft was placed. One patient with a decreasing aneurysm and poor proximal fixation who refused a secondary intervention had a contained rupture. He underwent successful open repair without any complications at an outside institution 22 months postimplantation.

Placement of proximal or distal extender cuffs was performed in 16 patients and was significantly greater in patients who had an increase or decrease in aneurysm diameter. Of the 16 patients who required secondary procedures, 10 proximal extender cuffs and 9 distal extender cuffs were placed. Only 9 (5.2%) of 170 patients with stable aneurysms required any secondary procedures. In patients who had an increase or decrease in aneurysm diameter, the number of secondary procedures was 5 (36%) of 11 and 5 (20%) of 25, respectively (*P* < .05).

### Table 2. Postoperative Changes in Abdominal Aortic Aneurysms and the Incidence of Type II Endoleaks at 32 ± 12 Months Following Endovascular Aneurysm Repair

<table>
<thead>
<tr>
<th>Change in aneurysm size, mean ± SD, mm</th>
<th>Small (n = 30)</th>
<th>Medium (n = 92)</th>
<th>Large (n = 84)</th>
<th><em>P</em> Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease</td>
<td>-2.03 ± 6.5</td>
<td>-2.09 ± 6.1</td>
<td>-3.7 ± 7.7</td>
<td>.59</td>
</tr>
<tr>
<td>Stable</td>
<td>6 (2)</td>
<td>13 (12)</td>
<td>13 (11)</td>
<td>.83</td>
</tr>
<tr>
<td>Increase</td>
<td>83 (25)</td>
<td>82 (75)</td>
<td>83 (70)</td>
<td>.45</td>
</tr>
<tr>
<td>Endoleaks</td>
<td>10 (3)</td>
<td>5 (5)</td>
<td>3 (3)</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>13 (4)</td>
<td>22 (20)</td>
<td>19 (16)</td>
<td>.41</td>
</tr>
</tbody>
</table>

The primary objective of aneurysm treatment is to eliminate the risk of rupture and death. The advent of EVAR has allowed for safe and effective treatment in the prevention of aneurysm-related deaths and ruptures with follow-up to 4 years.13,14 The clinical success of EVAR has been defined as successful deployment of the endovascular device without death, type I or III endoleak, graft infection, or thrombosis. Prevention of aneurysm expansion is considered an important indicator of clinical success as well, and there are several reports that focus on the importance of aneurysm shrinkage as defining clinical success.7,13,16 Furthermore, increasing aneurysm size can be associated with greater complexity of the proximal aortic neck, possibly resulting in adverse outcomes. The purpose of this report was to compare morphologic changes and outcomes of small, medium, and large aneurysms following EVAR, and to determine the importance of aneurysm expansion or shrinkage following EVAR.

For patients with small, medium, or large aneurysms, there was no significant difference in the overall proximal aortic neck diameter. However, this may be related to a selection bias, as patients with an aortic neck greater than 26 mm were treated with open surgical repair. Patients undergoing open repair had larger aneurysms than those undergoing EVAR.8 More importantly, large aneurysms had a significant (27%) decrease in proximal aortic neck length. This decrease in neck length was also associated with a 3-fold increase in the number of patients with a neck angulation greater than 45°.

While patients with larger aneurysms had a proximal aortic neck with a shorter fixation zone and greater angulation, outcomes were no different from those of patients with small aneurysms. This is indicated by the lack of significant difference in technical or clinical success. The overall technical success was 99.5% (205/206), with only 1 patient requiring conversion to open repair at the time of the initial EVAR. This conversion was the result of a 90° angulation of the proximal neck in a patient with a large aneurysm (80 mm). The proximal neck could not be accessed, so the procedure was converted to an open repair. The patient recovered uneventfully.

Endovascular aneurysm repair was as successful in treating large as it was in treating small aneurysms in appropriately selected patients. Continued follow-up revealed no significant differences in morphologic outcomes among the 3 groups. There was a tendency for all aneurysms to shrink, with larger aneurysms shrinking the most. However, this shrinkage was small and not significantly different among groups. Overall, most aneurysms (83%) did not change in size.

Endovascular aneurysm repair was clinically successful in preventing aneurysm enlargement in 95% (195/206) of patients. In the 5% of patients with aneurysm enlargement, size was not a predictor. However, smaller aneurysms had the greatest tendency of aneurysm ex-
pansion (10%) in this series. Aneurysm expansion was treated by first securing adequate proximal and distal fixation. Proximal and distal extender cuffs were placed from just below the renal arteries to the iliac artery bifurcation bilaterally. Patients with a type II endoleak, adequate fixation, and increasing aneurysm enlargement had either transarterial embolization of the endoleaks (n=6), thrombin injection of the aneurysm sac (n=2), or laparoscopic ligation of collateral vessels (n=1). To date, this algorithm has been successful in preventing further aneurysm expansion and rupture. To try to identify the effect aneurysm shrinkage had on the stent graft, we defined aneurysm shrinkage as greater than or equal to 10 mm. This is in contrast with the definition of significant aneurysm expansion (≥5 mm) as defined by the Society of Vascular Surgery. To date, there is no reporting standard for aneurysm shrinkage.

While aneurysm shrinkage is felt to be important following EVAR, there is little data that support that aneurysm shrinkage decreases the risk of aneurysm rupture or aneurysm-related death. There have been reports of patients with shrinking aneurysms and no endoleaks with aneurysm rupture and/or limb thrombosis. In our series of patients, significant aneurysm shrinkage occurred in 12% but preoperative aneurysm size was not predictive. However, there was a tendency for medium and large aneurysms to shrink more than smaller aneurysms. Furthermore, significant aneurysm shrinkage or expansion was associated with the need for secondary procedures. Thus, small aneurysms often required a secondary procedure for aneurysm expansion, while larger aneurysms required treatment for aneurysm contraction.

Aneurysms that were morphologically stable required secondary procedures significantly less often (5.2%) than those that decreased or increased in size. The number of secondary procedures in these patients was 4 to 6 times higher. The changing morphologic characteristics of the aneurysm sac may result in movement of the graft, resulting in insecure fixation. In most cases, this can be treated with percutaneous methods, such as placement of proximal or distal extender cuffs. The morbidity and mortality of these secondary procedures has been low in our hands, with no deaths reported to date and a low incidence of surgical conversions (3 [1.4%] of 206).

Late surgical conversions were the result of poor patient selection or poor graft placement. All 3 patients had poor proximal neck anatomy preoperatively, with 2 having short, reverse-funnelled, angulated necks. The third patient had an angulated neck because the graft was placed too low in the initial procedure. During our 6-year experience, we have made significant changes in the technique and placement of our endografts. These changes include using 3-dimensional reconstructions to accurately identify the correct gantry angle so that the endograft is squarely placed, just below the lowest renal artery; placing the contralateral limb into the gate prior to pulling the runners on the main body to prevent downward pulling of the graft; and bringing the graft routinely down to the iliac bifurcation to maximize columnar strength. What effects these changes will have on long-term morphologic characteristics of aneurysms and on reducing the number of secondary procedures remains to be seen.

The incidence of type II endoleaks was 19%. The use of both CTA and duplex ultrasound to identify endoleaks may explain the higher incidence of endoleaks in this series. However, there does not appear to be a direct correlation of aneurysm expansion (n=11) with type II endoleaks (n=40).

In conclusion, large aneurysms increase 15% in neck angulation and decrease 27% in neck length compared with small aneurysms, with no difference in outcome in properly selected patients undergoing EVAR. Aneurysms that are stable following EVAR have a significantly lower incidence of requiring secondary procedures. Thus, aneurysms with changing morphologic characteristics should be followed up closely, and aneurysm shrinkage may not be clinically necessary for a successful outcome. Future strategies in endografting may need to focus on aneurysm stabilization to reduce the number of secondary procedures.

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REFERENCES

Michael B. Farnell, MD, Rochester, Minn: (Reading a discussion prepared by Dr Bruce Gewertz):

Dr Arko and colleagues present an exceptionally well-analyzed experience of endovascular aneurysm repairs. This group has been among the innovators in this field and has approached the technical elements of endovascular repair and durability with a scientific and self-critical view. It is a large experience and is distinguished by the use of a single type of graft, the Anurex graft. Among the information shared with us today is the very clear picture that larger aneurysms, ie, greater than 6 cm, present with shorter infrarenal necks and more angulation. These factors increase the complexity of repair. In their manuscript, to my reading, they do not prove the point first made to Chris Zarins and myself, Sy Glagov, a distinguished pathologist at the University of Chicago, that the natural history of aneurysms is that they enlarge both in diameter and length. These data show that as the length increases, the angulation at the neck becomes more acute.

The other interesting fact presented today is that most aneurysms do not shrink after endovascular repair. Rather, 4 out of 5 aneurysms, irrespective of the initial size, remain the same diameter during the follow-up period. This raises what appears to be a key question in endovascular aneurysm repair. That is, does an aneurysm need to shrink in order to demonstrate successful repair?

I would like to propose 4 additional questions to the authors. (1) They clearly outline their selection criteria for endovascular repair relating to the maximal diameter and length of the infrarenal neck. In their manuscript, to my reading, they do not indicate how many patients within each class of aneurysm were rejected for endovascular repair for anatomic reasons. In particular, were more large aneurysms treated by open surgery?

(2) Fewer secondary procedures were needed in aneurysms that did not change in size, and the smallest number of endoleaks, 13%, were seen in this group. This suggests that the most favorable consequence is for the excluded aneurysm to develop mature thrombus in its sac such that it does not get larger or smaller. Does this invite active attempts to thrombose the aneurysm sac to maintain these critical relationships and paradoxically prevent the aneurysm from shrinking?

(3) The authors note that only 36% of the 11 patients with endoleaks had a secondary procedure. What happened to the other 6 patients? Did the endoleaks spontaneously heal, or is a secondary procedure contemplated in the future?

(4) My final question continues to bedevil all of us who employ endovascular repairs. What should be done with the patient who demonstrates aneurysm expansion without definable endoleak? Do you ever feel comfortable following these patients and at what rate of expansion or maximal size do you get more concerned?

M. Ashraf Mansour, MD, Grand Rapids, Mich: I have a question regarding your current management of aneurysms. There have been 2 large trials, the ADAM trial, which was just published last June, and the UK (United Kingdom) trial, that both show that it is safe to observe asymptomatic infrarenal abdominal aortic aneurysms until they reach the diameter of 5.5 cm. I noticed in your paper of 206 aneurysms repaired, two thirds of the patients had an aneurysm of less than 5 cm in diameter. How do you manage the patients now who are asymptomatic? If you get a patient who has a 5.2-cm aneurysm, do you offer a repair for them if they are asymptomatic? (The second question relates to) if the size of the aneurysm is not a guide to the effectiveness of the repair, what are we going to look for in our serial CT (computed tomography) scans other than endoleaks? When do you specifically angiogram patients if the aneurysm expands or stays the same?

James R. DeBord, MD, Peoria, Ill: At the Pacific Northwest Vascular Society and the North Pacific Surgical Association meetings in Seattle recently, a number of referral centers in Seattle and Oregon have treated endograft infections. These graft infections have a high mortality and morbidity and may be the Achilles heel of this procedure. It may not be too unexpected since we are hanging a rag in a bag full of clot that has been advanced from the groin, and several procedures are required through the groin in order to make them work. Are you seeing endograft infections in your experience, and what is your periprocedural protocol?

Dr Arko: With regards to Dr Gewertz’ first question, how many patients were rejected for endovascular repair, and were more large aneurysms referred for open repair? We have previously reported and compared our endovascular experience with open aneurysm repair, and have found that our open aneurysms typically are larger. The endovascular cohort mean aneurysm size is about 5.8 cm and for open repair is 6.4 cm. Our eligibility rate for endovascular repair has been right around 53%. With regard to active attempts to thrombose the aneurysm sac, there are techniques being studied to stabilize the aneurysm sac and prevent any aneurysm expansion or shrinkage. Furthermore, we do not treat type II endoleaks unless there is aneurysm expansion. We have only had 2 patients who have had aneurysm expansion with type II endoleaks.

Dr Gewertz asked our current management for patients with aneurysm expansion without endoleak. Currently, our protocol is to ensure that there is adequate proximal and distal fixation. We believe that this is the most important aspect of endovascular repair. Thus, we will make every effort to place extenders from just below the renal arteries to the iliac bifurcations bilaterally. Early in our experience, grafts may not have been placed right at the level of the renal arteries for the risk of renal artery thrombosis, and distally, the iliac limbs were brought into the iliac arteries without maximizing fixation. By maximizing this fixation and improving the columnar strength of the graft, we have had very few patients with this phenomenon.

In patients with aneurysm expansion and maximal fixation of the graft, I would recommend that both the CT angiogram and duplex ultrasound be performed to rule out any possible endoleak. If an endoleak was present, those patients should be treated with surgical conversion if there was no transcatheter technique to seal the endoleak.
Regarding Dr Mansour’s questions about the ADAM trial and the UK trial, that it is safe to observe aneurysms that are asymptomatic and less than 5.5 cm, 30 of the patients whom we treated had aneurysms less than 5 cm. These patients often were symptomatic or had aneurysms that were well over 2½ times the size of their proximal aortic neck. Also, some patients had aneurysms that were 4 to 4.5 cm. These patients were followed with duplex ultrasound at 6 months, and those with a rapid increase in size over a 3-to 6-month period were treated.

If I had an asymptomatic male patient with a 5.2-cm aneurysm, I tend to follow them with a repeat ultrasound at 3 to 6 months. If there was evidence of increased size, then I would get a CT angiogram and evaluate him for open or endovascular repair. With regards to treating small aneurysms, the ADAM trial and the UK trial were based on open surgical repair of the aneurysms. Oftentimes, the risk of operative mortality after open surgical repair typically ranges between 5% to 10%. In our own series, mortality for open repair is 3.2% and the mortality of endovascular repair has been very very low, at 0.3%. With such a low operative mortality for endovascular aneurysm repair, treating patients with smaller aneurysms may become more practical.

Regarding aneurysm size, it is important on follow-up surveillance, Dr Mansour. What you really want to look for is maintaining maximum proximal and distal fixation of the stent graft to prevent aneurysm rupture and migration. Endoleak is important as well. But from our data, aneurysm shrinkage does not appear to be important in preventing the primary outcome measures of aneurysm rupture and aneurysm-related death. If you look at the Eurostar data, they have also found that aneurysm shrinkage is related to the need for further secondary procedures. We need to maybe clarify that aneurysm shrinkage now is not as important as we once thought.

Dr DeBord wanted to know in the future if we should be basing our graft selection on the anatomic criteria of the aneurysm morphology, specifically with regard to hooks. If you look at the clinical trials of the various devices and trial, the US multicenter clinical trial required only a 10-mm-long proximal neck. All of the other clinical trials, including the Cook Zenith graft, the Ancure graft, and the Gore excluder graft, all of which have some type of hook or barb, all require a 15-mm neck. The hooks are really not to prevent or secure fixation or prevent endoleaks. Their main function is an attempt to prevent migration of the graft. The AneuRx graft does not have hooks, and fixation is based on radial force and columnar strength of the graft. By bringing the graft all the way down to the iliac bifurcations bilaterally, the columnar strength of the graft is maximized, and fixation improved both proximally and distally. Columnar strength is probably just as if not more important than the radial force and hooks or barbs. However, with the increasing number of grafts, there are certainly some grafts that will be more suited for certain types of aneurysm morphology.

End arteries are arteries that do not anastomose with neighboring arteries except through terminal capillaries. Obstruction of such an artery is likely to lead to local death, resulting in the case (a) of a cerebral artery, in paralysis, (b) of the central artery to the retina, in blindness, (c) of a branch of the renal or splenic artery, in death of a segment of the kidney or spleen, (d) of two or three adjacent vasa recta of the gut, in gangrene of the gut, and for the artery to the appendix.