Persistent collateral perfusion of abdominal aortic aneurysm after endovascular repair does not lead to progressive change in aneurysm diameter

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Purpose: To differentiate between the phenomenon of collateral perfusion from a side branch versus graft-related endoleaks after endovascular repair of abdominal aortic aneurysms (AAA), with respect to aneurysm size and prognosis.
Methods: We successfully treated 64 AAA patients with endovascular grafting. We followed all the patients postoperatively with spiral computed tomography at one, three, six and 12 months, and biannually thereafter. We measured aneurysm diameters preoperatively and postoperatively. We calculated preoperatively the relation of maximum aortic diameter (D) to the thrombus-free lumen diameter (L) expressed as an L/D ratio. Median follow-up was 15 months.
Results: Sixteen patients had collateral perfusion during follow-up. We successfully treated two patients with embolization. One patient showed resolution of collateral perfusion after we stopped warfarin treatment. Two patients died of unrelated causes during follow-up. One patient was converted to surgical treatment, and two patients showed spontaneous resolution of their collateral perfusion. The group of patients with perfusion showed no statistically significant change of their aortic diameter on follow-up. The group of patients without perfusion showed a median decrease in aortic diameter of 8mm ($p < 0.0001$) at 18 months postoperatively. The group of patients with perfusion had significantly less thrombus in their aneurysm sac preoperatively than the group without perfusion, as expressed by the L/D ratio (mean L/D 0,61 versus 0,78, respectively; $p = 0.0021$.)
Conclusion: There was no significant increase in aortic diameter on an average 18 months postoperatively despite persistent collateral perfusion. This may indicate a halted disease progression in the short term. Embolization of collateral vessels is associated with risk of paraplegia. We recommend a conservative approach with close observation if aneurysm diameter is stable. (J Vasc Surg 1998;28:242-9.)

Endovascular grafting of abdominal aortic aneurysms has become increasingly used over the last years.[1-3] When successful, it leads to exclusion of the aneurysm sac. Unlike conventional open repair, it does not enable control of side branches. We have previously shown that successful exclusion leads to a drop in pressure within the aneurysm sac.[4] However, we have been concerned about a number of our patients showing perfusion of the aneurysm through collateral vessels on follow-up and the effect that this might have on aneurysm growth. Other authors have also raised concerns about this complication, but have given no conclusive answer.[2,5,6] The mixing of patients with perfusion through collateral vessels and patients who have had endoleaks[5,6] from the proximal or distal stentgraft anastomoses, midgraft leaks, or a leak at the site of the occluder in the contralateral common iliac artery have also clouded results. We now believe these are two separate groups with the latter mainly a result of initial technical mishaps or the remodeling process of the aneurysm during follow-up and the former caused by naturally existing vessels. The aim of this study was to see what effect,

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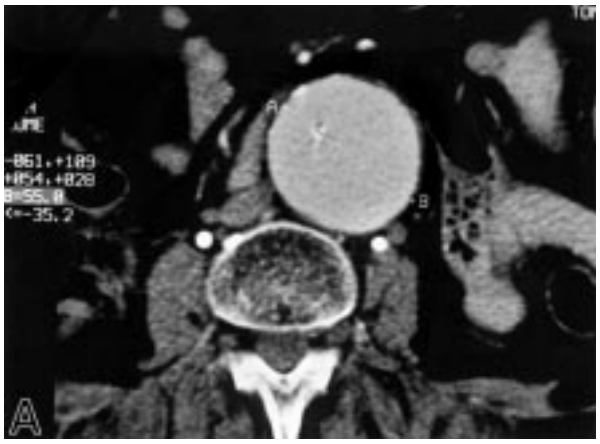

Fig. 1a. A preoperative spiral computer tomography axial scan of AAA with very little amount of thrombus in the aneurysm sac.

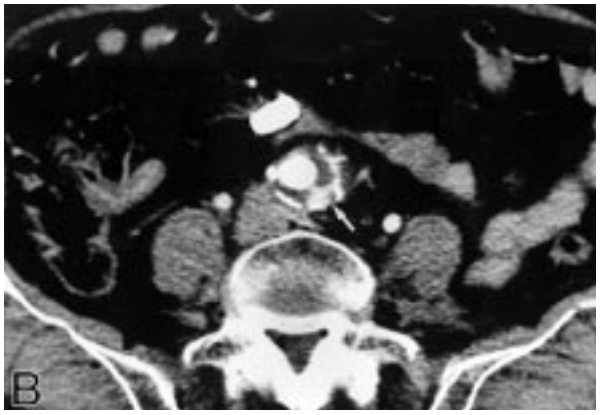

Fig. 1b. Postoperative spiral computed tomography in the same patient showing small amount of contrast accumulation in the sac secondary to collateral perfusion. The contrast was seen only on two axial 3-mm slices.

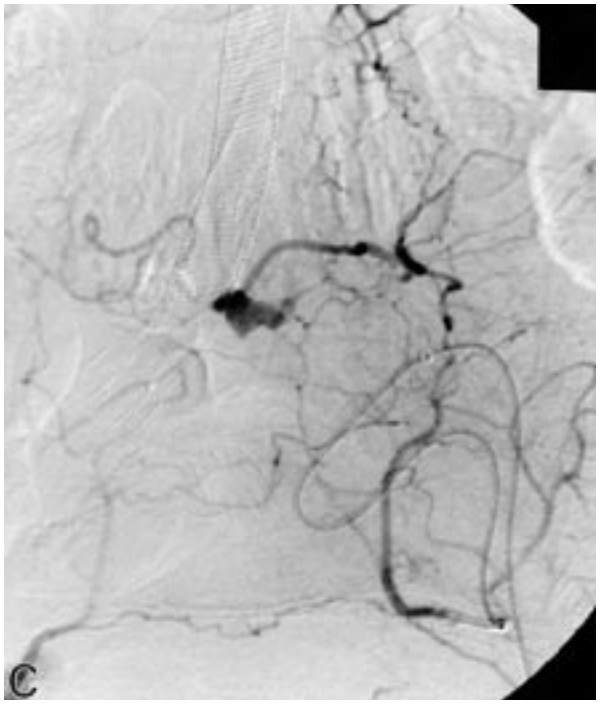

Fig. 1c. To find the origin of the perfusion, an angiography was performed showing perfusion through a iliolumbar artery.

if any, persistent *perfusion* of the aneurysm sac through collateral vessels had on the continued growth of the aneurysm.

MATERIALS AND METHODS

From November 1993 through August 1997, we treated 81 patients (nine women and 72 men) with endovascular grafting of a true AAA. This study excluded seven patients who showed signs of persistent endoleak during follow-up and seven more patients subjected to immediate operative conversion. We excluded three additional patients who went to another hospital for follow-up because it did not allow for adequate analysis and did not adhere completely to follow-up protocol. Thus, we included only patients that showed no signs of persistent endoleak (n = 64) so this would not be a factor in further aneurysm development. In three patients, we successfully embolized endoleaks at early postoperative follow-up and detected collateral perfusion following the embolization. The study included these patients at the time of collateral perfusion detection, but used only the interval after the closure of the initial endoleak. All patients received either aorto-uniiliacal (Ivancev-Malmö system[7]) or bifurcated (Chuter[8] or Vanguard[9]) endograft systems. We used contrast medium enhanced spiral computed tomography with 5-mm collimation, 5-mm table movement and 3-mm reconstructed axial slices, along with multiplanar (MPR) and three-dimensional reconstruction for preoperative evaluation in all patients. One-month and one-year follow-ups used intraarterial contrast injections. We always used a set of pre-contrast scans to rule out calcification or thrombus, which one can mistake for collateral perfusion. We also performed arteriograms with a calibrated catheter to evaluate aneurysm morphology. Follow-up consisted of spiral computed tomography at one, three, six and 12 months, and biannually thereafter. We performed angiograms postoperatively at one month and after that when deemed clinically necessary.

Table I. Characteristics of patients with collateral perfusion

Patient Number	*Type of Perfusion*	*Discovered*	*Course of Action*	*Current Status (follow-up time=months)*
1	LA	3 mo	N	CP (36)
2	LA	2 mo	Embo 2 mo-S	NP (36)
3	LA	3 mo	N	CP (30)
4	IMA/LA	2 days	Embo 12 mo	CP (30)
5	LA	2 days	N	converted-prox migration
6	LA	12 mo	N	CP (30)
7	LA	1 mo	Sp res 12 mo	NP (24)
8	IMA	1 mo	Warfarin stopped	NP (24)
9	LA	3 mo	Embo 6 mo	CP (24)
10	LA	1 mo	Embo 6 mo-S	NP (18)
11	LA	1 mo	Embo 6 mo	meningitis postop-died
12	IMA	1 mo	N	CP (12)
13	LA	1 mo	N	cerebral bleed postop-died
14	LA	1 mo	N	CP (12)
15	LA	1 mo	Sp res 6 mo	NP (6)
16	LA	1 mo	N	CP (3)

LA, lumbar artery; *IMA,* inferior mesenteric artery; *mo,* month; *Embo,* embolization; *Sp res,* spontaneous resolution; *N,* none; *CP,* collateral perfusion; *NP,* no perfusion; *S,* successful.

We measured maximum AAA diameter at the widest part of the aneurysm. To avoid miscalculations as a result of tortuosity, we measured the shortest diagonal (D), thereby avoiding overestimation of aneurysm size on slices where the aneurysm appeared oval. At this same level, we also measured the corresponding diameter of the aortic thrombus-free lumen (L) and calculated the quotient L/D to estimate the amount of thrombus in the aneurysm sac (Fig. 1a). Because we lacked appropriate computer software, we did not measure on MPR.

You can see the presence of collateral perfusion most readily on spiral computed tomography scans; however, we performed an angiogram (including selective catheterization of hypogastric arteries) when we detected collateral perfusion to try to elucidate the origin of the perfusion (Fig. lc).

For the analysis in this study, we excluded a patient with collateral perfusion when the perfusion stopped at any time, whether this occurred spontaneously or by a radiological intervention. Surgical conversion or patient death was the reason for exclusion in both groups.

The median (M) follow-up time was 15 months. Interquartile range (IQR) was 3 to 24 months. (Totally excluded were M = 12, IQR 3-20 months; perfused M = 18, IQR 3-24 months.)

This study could show normal distributions only for the ratio L/D, and, therefore, used unpaired Student *t*-test only for analysis of this variable. For all other variables, this study calculated medians and IQR and used Wilcoxon's rank sum test for analysis of paired data and Mann-Whitney test for unpaired comparisons. The study gives exact *p*-values and considers them significant when $p < 0.05$.

The institutional review board approved this study, and all patients gave informed consent before surgical intervention and radiographic studies.

RESULTS

The median maximum AAA diameter preoperatively was 54 mm (IQR 47-60 mm.) Sixteen patients (25%) showed signs of collateral perfusion during follow-up. Table I shows the characteristics of the perfusion in the individual cases and course of action, if any, against it. As noted, a majority of the perfusions visualized early during follow-up. When this was not the case, we delayed diagnosis because the patient did not receive a computed tomography at 1 month postoperatively (n = 2; patients 1 and 2 in Table I received treatment early in the series when the protocol was not yet fully established). We also delayed diagnosis when the patients initially showed concomitant endoleak (n = 3; patient 3 in Table I showed a perioccluder leak, patient 6 a leak at distal anastomosis and patient 9 a perioccluder leak). In these cases the diagnosis of collateral perfusion was made apparent only after embolization closed the endoleaks. Most cases of collateral perfusion were small and visible only on one or two 3-mm axial computed tomography slices (Fig. lb). There was no statistical difference in the size of the aneurysm preoperatively between the group that had collateral perfusion and the one that did not. However, the group of patients with collateral perfusion did have significantly less thrombus in their aneurysmal sac than the

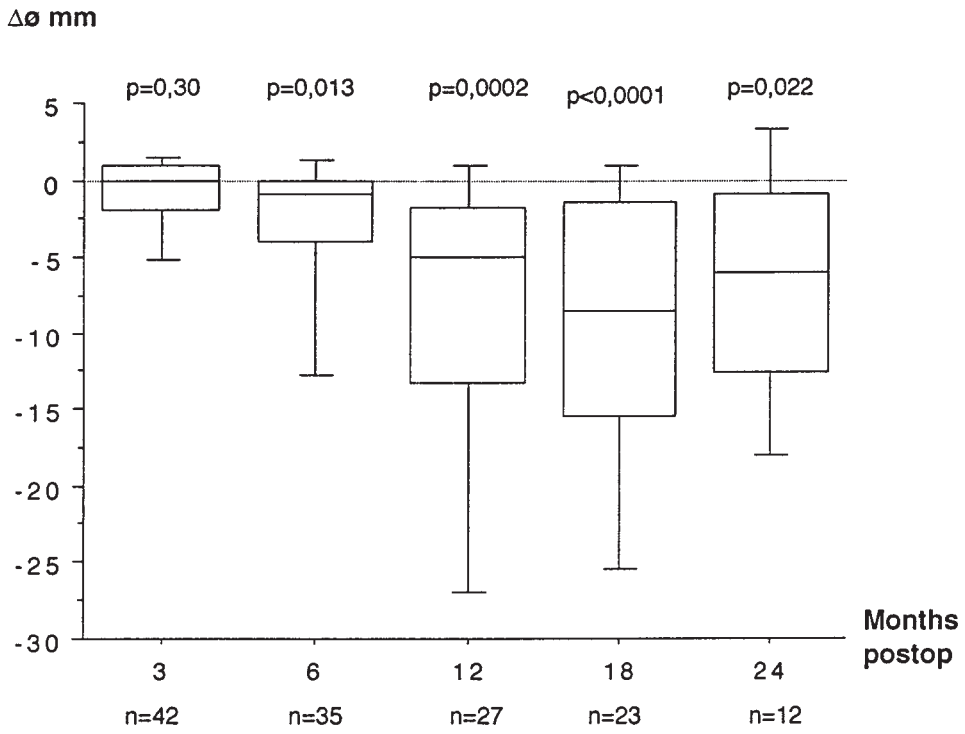

Fig. 2. Change (Δ) in maximum AAA diameter in patients with totally excluded AAA. Median, 10th, 25th, 75th and 90th percentiles shown. *p*-values above each box plot refer to cumulative changes.

group without perfusion. (Mean L / D = 0.78 (SD±0.21) for the group with perfusion compared to mean L / D = 0.61 (SD±0.17) for the group without perfusion or leaks. $p = 0.0021$.)

The group of patients without perfusion or endoleaks (n = 48) showed a statistically significant decrease in aneurysm size postoperatively (Fig. 2). The median reduction at 18 months was 8 mm (IQR 4-16mm). There was no correlation between the size of the aneurysm preoperatively and the postoperative decrease in size.

The group of 16 patients with no signs of collateral perfusion showed no statistically significant cumulative increase or decrease in AAA diameter postoperatively at the different follow-up intervals (Figs. 3 and 4). However, the median change in aortic diameter at 18 months was a 3-mm decrease (IQR +3 to -6 mm). Currently, eight patients continue to have collateral perfusion.

Comparisons of the aortic diameters postoperatively between the group with collateral perfusion and the group with totally excluded AAA failed to show any statistically significant difference in the reduction of aneurysm size. At 18-months follow-up, the aneurysms in the group without perfusion had decreased an average 7.5 mm more than the group with perfusion ($p = 0.06$).

Table II. Change in aortic diameter after collateral perfusion stopped

Patient Number	*Follow-up time (mo) after perfusion stopped*	*AAA compared to preoperative (mm)*
2	34	-6
7	12	-1
8	24	-12
10	12	-4
15	0	—

Patient numbers correspond to numbers in Table I. Patient 15 has not yet been to follow-up after perfusion ceased, and therefore, measurement of aortic diameter is not available.

The two patients successfully treated with coil embolization (patients 2 and 10 in Table I) after the procedures showed a decrease in AAA diameter of 6 mm and 4 mm, respectively (see Table II).

DISCUSSION

Since the practice of endovascular stentgrafting (EVG) of abdominal aortic aneurysms started in the

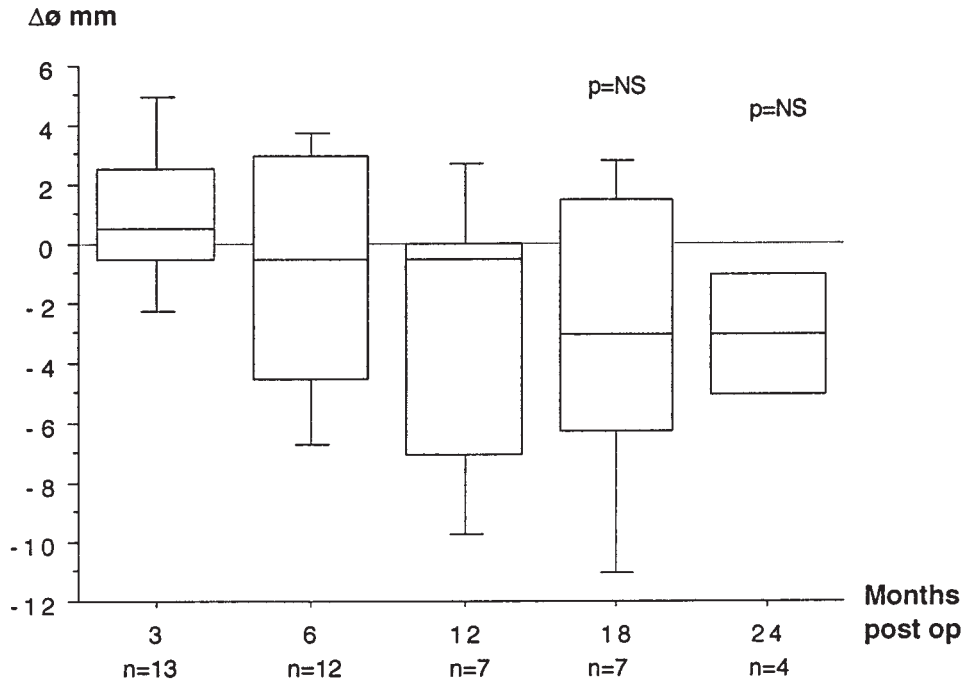

Fig. 3. Change (Δ) in maximum AAA diameter in patients with collateral perfusion of AAA. Median, 10th, 25th, 75th and 90th percentiles shown. *p*-values above each box plot refer to cumulative changes.

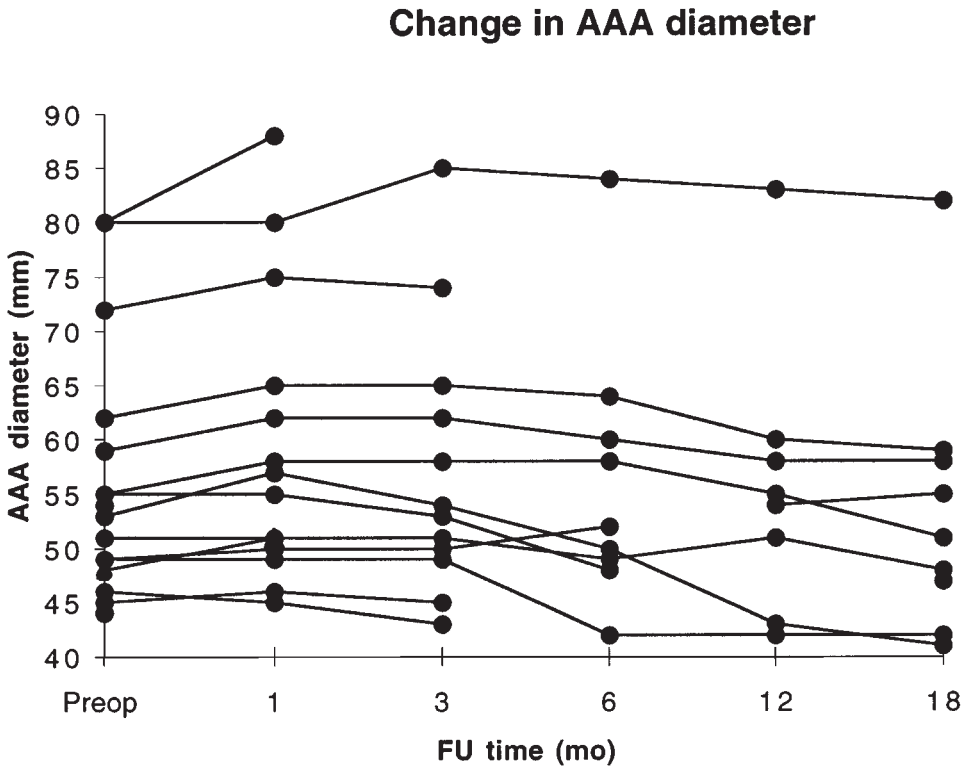

Fig. 4. Aortic aneurysm diameter at follow-up (FU) in patients with collateral perfusion. Only intervals with ongoing perfusion are shown.

beginning of the 1990s, several centers around the world have adopted the technique. Most investigators have shown that EVG is a feasible procedure in a selected group of patients with good short-term results.[9-11] However, many questions concerning long-term follow-up are still unanswered. One unanswered question, which has raised concern among several authors, is that some patients show signs of endoleaks during follow-up. This is noted as contrast medium accumulation in the aneurysm sac on a spiral computed tomography scan, which probably is the most sensitive modality for detecting endoleaks. Resnikoff et al.[12] stated that in patients operatively excluded for AAA with an aorta-iliac extra-anastomotic bypass and closure of the aneurysm sac, those with continuous perfusion of the aneurysm sac, with no reduction of the size of the sac postoperatively or continued wall pulsations, were at high risk for subsequent rupture. However, this was only 2% of the 831 analyzed patients. They also raise the concern that perigraft leaks after endovascular procedures may become the rate-limiting factor in the further development of this novel technique. In this context, we believe it is important to separate the phenomenon of perfusion through collateral vessels from endoleaks[11] (proximal, midgraft, distal or perioccluder) that occur as a result of technical failure of EVG. When studying the effect these two groups have on aneurysm expansion, mixing them makes it difficult to interpret the results. As we have shown in this analysis, we have not seen any continued dilatation of the aneurysm sac in patients with collateral perfusion. On the other hand, we have seen expansion in patients with endoleaks or where the proximal stent has migrated distally and left the aneurysm nonexcluded (unpublished data).

Another problem that deserves attention is the fact that the presence of collateral perfusion may be hard to demonstrate. For the presence of collateral perfusion, there must be both an inflow and an outflow from the aneurysm sac. Theoretically, one can speculate that even though the AAA seems to be totally excluded with no signs of contrast medium accumulation in the aneurysm sac, this may be caused by the fact that the timing of the CT scan is incorrect. A scan taken too early in relation to a slow perfusion flow might result in a negative finding. Delivery of a dense contrast medium directly into the aorta during spiral computed tomography (an intraarterial spiral computed tomography), which we performed at one-month and one-year follow-ups, may have contributed to the high rate of detection of collateral perfusion in our patients. In our follow-up protocol, we scan all our patients with spiral computed tomography scans with only 3-mm slice thickness. Many collateral perfusions are seen only on one or two slices and thus easily missed if follow-up uses thicker slices. We examine the scans very carefully, specifically searching for endoleaks or collateral perfusion. This might be an additional explanation to why we seem to have significantly more cases of collateral perfusion than other authors have reported.[1,13] Even so, small leaks can remain undiscovered and could explain some cases of seemingly well-excluded aneurysms that do not show a reduction in size on follow-up.[14] The angiograms at one-month follow-ups are not as good as spiral computed tomography for detecting small perfusions. We use the angiograms mainly as a baseline study for detecting a possible stent migration later in follow-up. The intra-operative angiograms made with a C-arm are not of the same quality as those made in a full angiography suite.

Another aspect of collateral perfusion postoperatively is to what additional procedures it should lead. We have presented previously the option of coil embolization of collateral vessels as a treatment.[15] Others recommend occlusion of major aortic side branches before EVG as a preventive measure.[7,16] In light of our results, there seems to be a need for studies in this area. One must keep in mind that no treatment is without risk. In one of the patients described in this study, we performed multiple coil embolizations in the same session. The patient suffered from transient paraplegia, probably due to the excessive embolization. Others[2,17] have chosen to just observe patients with collateral perfusion and have seen no aneurysm expansion, an approach congruent with the findings in this study. Our current criterion for treating a patient with collateral perfusion is aneurysmal enlargement of 5 mm or more compared with the preoperative measurement. We chose this limit because the errors of measurement for the individual patient are approximately 2 to 3 mm (unpublished data).

In this study, we found 16 patients with spiral computed tomography verified collateral perfusion that show no statistically significant increases in aneurysm size on an average follow-up of 18 months. We subjected five cases to coil embolization, but only two were successful. The latter two showed a decrease in AAA diameter after the intervention (6 and 4 mm, respectively). Two patients out of the 16 with collateral perfusion showed an increase in aneurysm diameter that led to an adjunctive procedure. One had concomitant graft separation as a plausible explanation for the progressive enlargement, which left only

one case of "true" expansion with collateral perfusion as the only reasonable explanation. This was one of the successful embolization cases. In addition, two patients had small cumulative increases in AAA diameter at 18 months (2 and 3 mm, respectively), but we believe these are within measurement error because they do not seem to be progressive when looking at previous follow-ups. The group of patients with total aneurysm exclusion showed a statistically significant decrease in AAA diameter on follow-up, a finding that has been shown previously.[5,6,18] However, we could not show any significant difference in postoperative decrease of AAA diameters between well-excluded aneurysms and those with collateral perfusion, possibly because the group of patients with collateral perfusion was small on later follow-up. Out of the 16 patients with collateral perfusion, only eight patients currently continue to have perfusion and are under close observation. We find it interesting that the patients who showed collateral perfusion on follow-up had significantly less thrombus in their aneurysm sac preoperatively as measured by the L/D ratio. However, a broad overlap between the groups makes preoperative discrimination difficult. This could suggest that patients with much thrombus have sealed off their lumbar vessels in contrast to those with less thrombus, where the collateral vessels are left patent with a chance of collateral perfusion to the aneurysm sac occurring.[19] The combined finding of little thrombus in the aneurysm sac and the inability to seal off collateral vessels implies clotting of the blood may be in some way disturbed. This theory is consistent with the finding in one of the patients who had collateral perfusion (patient 8, Table I), which ceased after warfarin treatment stopped. Our findings do not support an aggressive policy of coil embolization of tributaries before EVG, even if the AAA sac contains only a small amount of thrombus and, therefore, has a greater chance of collateral perfusion postoperatively.

In conclusion, this study shows no significant increase in AAA diameter on an average 18 months postoperatively, despite persistent collateral perfusion. Even though totally excluded AAA decrease in size postoperatively, the fact that AAA with collateral perfusion do not change in diameter may indicate a short-term halted disease progression compared to natural aneurysm growth.[20] The long-term risk of rupture is currently unknown. Adjunctive procedures to close collateral perfusion are not without risk, in our experience, and not successful in all cases. For patients with collateral perfusion and stable AAA diameter on follow-up, we currently recommend continued close observation instead of surgical procedures or intervention.

This study is part of the CATPEG within the EC Framework programme BIOMED, Contract no. BMH4-97-2250. Coordinator of the project: Professor Bo Risberg, Department of Vascular Surgery, Sahlgrenska University Hospital, Gothenburg, Sweden.

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Submitted Dec 15, 1997; accepted Feb 25, 1998.

CORRECTION

Fig. 2 was incorrectly printed in the February 1998 article entitled "Preoperative thromboxane A2/prostaglandin H2 receptor activity predicts early graft thrombosis" by Thomas E. Brothers et al. (J Vasc Surg 1998;27:317-28). The correct Fig. 2 and the appropriate legend appear below.

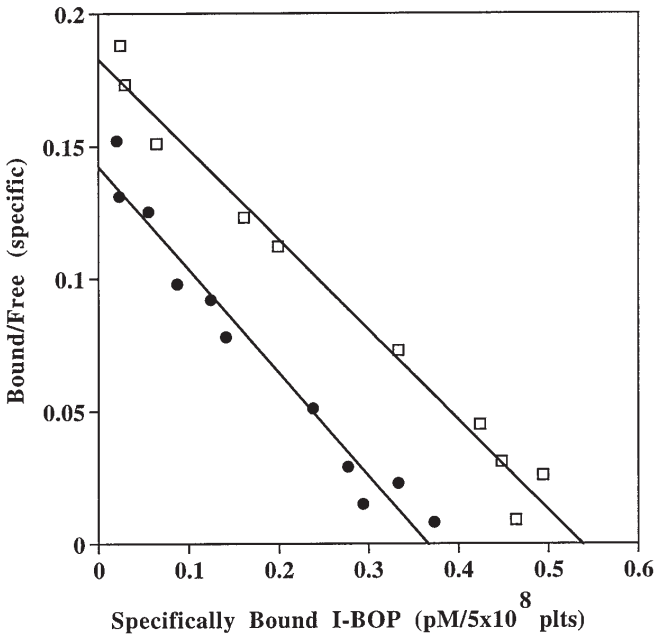

Fig. 2. Scatchard analysis of equilibrium binding data for [^{125}I]-BOP from platelets derived before operation. Nonlinear analysis (LIGAND program) of individual data from patients with thrombosed grafts *(open squares)* yielded an average dissociation constant (Kd) of 8.8 nmol/L and a receptor number (B_{max}) of 3100 sites/platelet, and analysis of patients with patent grafts *(filled circles)* yielded a Kd of 7.9 nmol/L and a receptor number (B_{max}) of 1500 sites/platelet. Individual patient data have been grouped according to either occluded or patent graft status for each concentration of unlabeled ligand in this figure for ease of illustration.