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Freedom From Endoleak After Endovascular Aneurysm Repair Does Not Equal Treatment Success*

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Objective: *to determine whether freedom from endoleak after endovascular repair of abdominal aortic aneurysm (EVAR) is a reliable guide to freedom from persistent or recurrent pressurisation of the aneurysm sac (endotension) and therefore freedom from risk of rupture.*
Patients and methods: *the records of 55 patients followed for more than 3 months after EVAR were reviewed to correlate the presence or absence of endoleak on contrast-enhanced CT and/or angiography with changes in maximum aneurysm diameter (DMAX).*
Results: *in 22 (40%) patients there was no significant change in DMAX during follow-up. In 21 of these no endoleak was observed on CT or angiography. One patient developed a secondary side-branch endoleak which remains under observation. In 18 (33%) patients, DMAX decreased during follow-up. Thirteen of these remained free of endoleak. Four patients developed secondary endoleaks which were treated by secondary intervention. One patient with persistent primary endoleak suffered fatal aneurysm rupture three days before planned intervention. DMAX increased in 15 (27%) patients. In only five of these could an endoleak be identified on CT and/or angiography. One primary side-branch endoleak persists following failed embolisation. Four secondary endoleaks have been corrected by secondary intervention. Four of the remaining 10 patients died suddenly from unknown cause. All had DMAX greater than 65 mm at last follow-up. One patient underwent late conversion, which suggested continued pressurisation through thrombus at the site of a ''sealed'' primary proximal endoleak. Two patients are scheduled to undergo embolisation of patent side-branches revealed only by Levovist enhanced Duplex scanning and three patients remain under observation.*
Conclusion: *freedom from endoleak on conventional imaging incorrectly suggested freedom from endotension in 10 (18%) of our patients. Follow-up after endovascular repair must include regular measurement of DMAX and/or aneurysm sac volume to identify those patients who remain at risk of rupture.*

Key Words: Endovascular aneurysm repair; Endoleak; Endotension.

Introduction

Endovascular repair of abdominal aortic aneurysm relies on isolation of the aneurysm from the circulation to eliminate or reduce pressure within the aneurysm sac and thus prevent potentially fatal rupture of the aneurysm. Since it is not, at present, possible to measure intra-sac pressure directly for more than a few days after operation, the success of endovascular repair can only be evaluated indirectly by observation of changes in the diameter or volume of the aneurysm sac or by the presence or absence of endoleak.

An endoleak is certainly evidence of persistent or recurrent communication between the circulation and the aneurysm sac and, for this reason, is generally believed to signify failure of treatment.[1–3] Conversely, freedom from endoleak on follow-up imaging has become widely accepted as evidence of successful treatment.[4]

The validity of these assumptions was examined by review of the records of all patients who had undergone endovascular repair at our institution.

Patients and Methods

We identified 55 patients who had been followed for at least 3 months after endovascular aneurysm repair. Forty-four (80%) were male and 11 (20%) were female. The median age was 71 years (range 50–87). Excluded from this study were two patients who had died within

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30 days of operation, and a further eight patients who had been treated within three months of the analysis.

All patients were followed according to the Eurostar protocol.[4] Contrast-enhanced spiral CT scanning was performed within 1 month of operation and at 3, 6, 12, 18, 24 and 36 months after operation. Angiography was performed routinely at 12 months after operation and selectively in patients in whom CT scanning suggested endoleak. Since January 1999 patients have in addition been examined by Levovist enhanced duplex scanning.

The CT scans were examined by one of two vascular radiologists for evidence of endoleak and to assess changes in the morphology of the aneurysm sac and the stent-graft. Maximum aneurysm diameter (DMAX) was measured as well as the diameter of the infrarenal neck and the length of the aneurysm sac. Whenever measurements differed significantly from those made previously, all films were reviewed to ensure that comparable dimensions were being measured.

Data on these 55 patients were reviewed in order to determine the incidence and fate of endoleaks in patients with shrinking aneurysms, enlarging aneurysms and aneurysms that neither shrunk nor expanded. A change in DMAX was only considered significant if greater than 2 mm and observed on more than one follow-up examination.

Results

Patients were followed for a median of 18 months (range 3–36). Eight patients died and a further two patients were lost to follow-up. There were two graft-related deaths. One patient suffered fatal rupture of his aneurysm 4 months after operation and one developed systemic sepsis secondary to graft infection 12 months after operation. Two patients died from unrelated causes (bronchopneumonia and malignancy) and four patients suffered sudden unexplained deaths.

Endoleaks

A primary endoleak was noted on pre-discharge CT scan in 11 (20%) patients. There were six Type I (graft-related) endoleaks (two proximal, four distal) and five Type II (side-branch) endoleaks. Seven (64%) of these were not apparent on any subsequent CT scan and were deemed to have sealed spontaneously. Two (one distal and one side branch) were treated by secondary endovascular intervention within 1 month of operation and did not recur. There were two persistent primary endoleaks. One proximal endoleak resulted in fatal rupture of the aneurysm 5 days before planned conversion to open repair and one lumbar side branch endoleak persists following failed embolisation.

A further nine patients were noted on follow-up CT scan to have developed a secondary endoleak. Seven of these were Type I endoleaks (four mid-graft, three distal) and two were Type II endoleaks. All developed between 12 and 24 months after operation. Distal and mid-graft endoleaks were successfully treated by secondary endovascular intervention. One patent inferior mesenteric artery in a patient with an expanding aneurysm was treated by laparoscopic clipping of the mesenteric artery. One lumbar endoleak in a patient with a static aneurysm persisted at last follow-up.

Postoperative CT surveillance thus identified eleven patients with persistent primary (two) or secondary (nine) endoleaks who could be considered still to be at risk from rupture of their aneurysm and in whom primary intervention could, therefore, be said to have failed.

Aneurysm diameter

The median preoperative DMAX was 58 mm (range 45–90 mm). In 22 (40%) patients there was no significant change in DMAX during follow-up (Table 1). In 21 of these no endoleak was observed on CT or angiography. One patient developed side-branch endoleak at 6 months and remains under observation.

In a further 18 (33%) patients DMAX decreased during follow-up by a median of 7 mm (range 3–19 mm). No endoleak was identified in 13 of these patients. Four patients developed secondary mid-graft (two) or distal (two) endoleaks which were treated by secondary endovascular intervention. One patient suffered fatal rupture secondary to persistent proximal endoleak as described previously.

Persistent (seven) or recurrent (eight) expansion of the aneurysm sac was observed in 15 patients (27%). In these, DMAX increased by a median of 9 mm (range 6–17 mm). In only five of these patients could an endoleak be identified on routine follow-up CT scanning and/or angiography. Four of the remaining 10 patients have died suddenly from unknown cause. All had DMAX greater than 65 mm (range 65–95 mm) at last follow-up. One patient underwent late conversion to open repair 2 years after operation. DMAX had increased from 62 to 79 mm during follow-up. A proximal endoleak had been noted on pre-discharge CT

Table 1. Relationship between change in aneurysm diameter and presence or absence of endoleak.

Group 1 ($n=22$)	No change	21	No endoleak on CT/angio	
		1	Secondary Type II endoleak	(not treated)
Group 2 ($n=18$)	Aneurysm shrinking	13	No endoleak on CT/angio	
		4	Secondary Type I endoleak	(treated)
		1	Persistent primary Type I endoleak	(fatal rupture)
Group 3 ($n=15$)	Aneurysm expanding	10	No endoleak on CT/angio	
			4 sudden death (? cause)	
			1 late conversion (sealed endoleak)	
			2 Type II endoleak on duplex scan	
			3 under observation	
		3	Secondary Type I endoleak	(treated)
		1	Secondary Type II endoleak	(treated)
		1	Persistent primary Type II endoleak	(lost to follow-up)

scan but no endoleak could be identified on any subsequent follow-up imaging. Surgical exploration of the aneurysm sac revealed a persistent primary proximal endoleak sealed with a loose plug of thrombus which, it is presumed, had continued to transmit pressure but not flow. Two patients are scheduled to undergo embolisation of secondary side branch endoleaks noted only on Levovist enhanced duplex scanning. Three patients with increasing DMAX remain under observation.

Thus, if we assume that aneurysms which are not enlarging are not at risk of rupture, "freedom from endoleak" (observed in 44 of 55 patients in our series) correctly identified freedom from risk of aneurysm rupture in 34 patients (i.e. 77% of those who were free of endoleak (sensitivity) or 62% of all patients in the series). Conversely, if we assume that continued expansion of an aneurysm is evidence of continued or recurrent pressurisation of the aneurysm sac (which we have defined as endotension), then freedom from endoleak incorrectly suggested freedom from endotension in 10 patients (i.e. 23% of those who were free of endoleak or 18% of all patients in the series). Increasing aneurysm diameter was only observed in five of 11 (45%) patients with endoleak but four of the remaining six patients underwent secondary intervention and might well have gone on to aneurysm expansion if this had not been performed.

Discussion

The purpose of radiological surveillance following endovascular repair is to detect those patients who remain at risk from rupture of their aneurysm. Endoleak has been defined as persistent or recurrent flow of blood within the aneurysm sac but outside the stent graft.[3] An endoleak is, therefore, evidence of persistent or recurrent communication between the circulation and the aneurysm sac. The widespread belief that an endoleak is evidence of treatment failure assumes that all endoleaks maintain intra-sac pressure at or close to systemic arterial pressure. While it is highly likely that this is true for Type I (graft-related) endoleaks there is growing evidence that some Type II (side-branch) endoleaks may, in fact, be at substantially less than systemic arterial pressure. Analysis of the Eurostar database reveals a significant number of patients with shrinking aneurysms despite persistent side branch endoleak.[5] Other groups have reported similar findings.[6]

More worrying is the belief that freedom from endoleak equals freedom from persistent or recurrent pressurisation of the aneurysm sac (endotension). The absence of evidence should not be mistaken for the evidence of absence. Experiments in our laboratories have demonstrated that intra-sac pressure can be maintained by side branch endoleaks with a flow rate of less than 1 ml/m.[7] Such low flow rates would be unlikely to be visualised on conventional imaging. It is also known that thrombus is a semi-fluid medium that can transmit pressure.[8] In our series one patient who underwent late conversion was found at operation not to have any evidence of back-bleeding into the aneurysm sac. We concluded that intrasac pressure must have resulted from transmission of pressure through thrombus sealing a proximal endoleak. Another possible source of intra-sac pressure is transmission of arterial pressure through the fabric of the stent graft. Some of the ultra-thin fabrics used are semi-porous and rely on thrombosis within the interstices of the graft material immediately after implantation to effect a seal. Whether or not such devices can transmit pressure to the aneurysm sac is simply not known.

In our series, freedom from endoleak during follow-up suggested that 44 (80%) of the patients were free

Table 2. Follow-up and devices employed in patients with shrinking or expanding aneurysms and in those with no change in aneurysm diameter.

	Group I ($n=22$) (no change in aneurysm diameter)	Group II ($n=18$) (decrease in aneurysm diameter)	Group III ($n=15$) (increase in aneurysm diameter)
Follow-up	Median 6 months (Range 3–36 m)	Median 18 months (Range 3–36 m)	Median 18 months (Range 6–36 m)
Devices	Device A 7 Device B 11 Others 4	Device A 14 Device B 2 Others 2	Device A 10 Device B 4 Others 1

from the risk of aneurysm rupture. In fact, continued or recurrent expansion of the aneurysm sac was observed in 10 of these patients, four of whom died suddenly of unknown causes. We believe that expansion of an aneurysm implies persistent or recurrent pressurisation (we cannot readily conceive of an alternative explanation) and since the four patients who died all had maximum aneurysm diameters in excess of 65 mm, it is difficult to believe that none of these patients died as a result of rupture. Thus, freedom from endoleak incorrectly suggested freedom from endotension in 10 of the 44 patients (23%).

It could with hindsight be argued that a different imaging protocol might have revealed endoleaks in some of these ten patients. It was our practice to perform single (arterial) phase contrast-enhanced CT (imaging 28 s after injection of contrast). We are aware of reports suggesting improved sensitivity to low-flow endoleaks with dual (arterial plus delayed) phase contrast-enhanced CT[9] but in a limited study of this technique we have not identified any endoleaks on dual phase CT that were not identifiable on single phase CT. It should also be noted that in four of these 10 patients, no endoleak has been observed despite repeated imaging and a high index of suspicion. Further studies into alternative imaging protocols in such patients are awaited with interest.

Shrinkage of the aneurysm is convincing evidence of depressurisation, but was observed in only 13 of the 44 patients who were free of endoleak on follow-up imaging. In a further 19 patients without endoleak, there was no significant change in aneurysm diameter throughout follow-up. The assumption that aneurysms which neither shrink nor expand are no longer at risk of rupture is based more on optimism than any scientific evidence. Since the mechanism of aneurysm shrinkage following endovascular repair is not understood, it is not possible to explain why some aneurysms shrink while others do not. The suspicion must remain, therefore, that aneurysms which do not shrink are still under pressure and, therefore, at risk of rupture. In our series, shrinkage (Table 2, Group II) was observed more frequently with one type of device whereas failure to shrink (Table 2, Group I) was observed more frequently with another type of device. Aneurysm shrinkage was also more frequent in patients who had been followed for longer and it is, therefore, unwise to draw too many conclusions from an apparent association with device type. It would, however, be equally unwise to reject the possibility that some devices continue to transmit sufficient pressure for the aneurysm to remain at risk of rupture.

What is clear is that freedom from endoleak is an unreliable guide to treatment success. If it is intra-sac pressure which is responsible for aneurysm rupture and blood flow into the aneurysm sac which results in haemorrhage following rupture, it follows that it is freedom from persistent or recurrent pressurisation of the aneurysm sac or endotension that is the true determinant of successful endovascular repair. Until it becomes possible to monitor intra-sac pressure directly throughout follow-up, surveillance after endovascular repair must include regular evaluation of aneurysm diameter and/or volume in addition to regular imaging to detect endoleak.

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