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Original article

The impact of interventional neuroradiology on neurosurgical training

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Aneurysmal subarachnoid haemorrhage carries a high mortality and morbidity. Surgical treatment (craniotomy and clipping of the aneurysm) has been, until recently, the gold standard treatment. Endovascular embolisation treatment has rapidly evolved and the evidence available suggests that the results are as good as surgery. Endovascular treatment successfully occludes the aneurysm to prevent re-haemorrhage, whilst reducing the procedural morbidity when compared to craniotomy and clipping. It is perceived to be of particular benefit for aneurysms in the posterior cerebral circulation where operative morbidity and mortality are significantly higher than for aneurysms on the anterior circle of Willis. The establishment of endovascular treatment has reduced the number of cases being treated surgically, and this has had a significant effect on surgical training. We analysed the management of all ruptured aneurysms treated in our unit over a 4-year period. During the same period, an endovascular service was established in the unit. We devised a novel system for the angiographic grading of aneurysms in order to evaluate the impact that coiling has had on surgical training. The results show that as few as four aneurysms per year would be appropriate for specialist registrars to operate upon. We propose some mechanisms for maintaining high quality surgical training.

Key words: Intracranial aneurysm – Subarachnoid haemorrhage – Surgery – Training – Endovascular treatment

Subarachnoid haemorrhage (SAH) is a devastating condition. Untreated, the overall 30-day mortality is 50–60% and half of the survivors will have major disability.[1,2] Cerebral aneurysms arising from the circle of Willis are responsible for 80% of SAH. The aetiology of these aneurysms remains uncertain, but the relationship to haemodynamic stresses at branch points is the favoured view (Fig. 1).[3]

Ruptured aneurysms need to be excluded from the circulation to prevent further haemorrhage. Re-bleeding is associated with a much worse outcome. Until recently microsurgery was the only treatment. This involves craniotomy, brain retraction, vessel dissection and the application of a metal clip across the neck of the aneurysm. The development of interventional neuroradiology techniques has provided a viable alternative treatment. Endovascular treatment involves the passage of microcatheters up into the cerebral arterial circulation, usually by a transfemoral approach, through which suitable material (*e.g.* coils or glue) may be deployed to occlude the aneurysm sac (Figs 2 & 3).[4]

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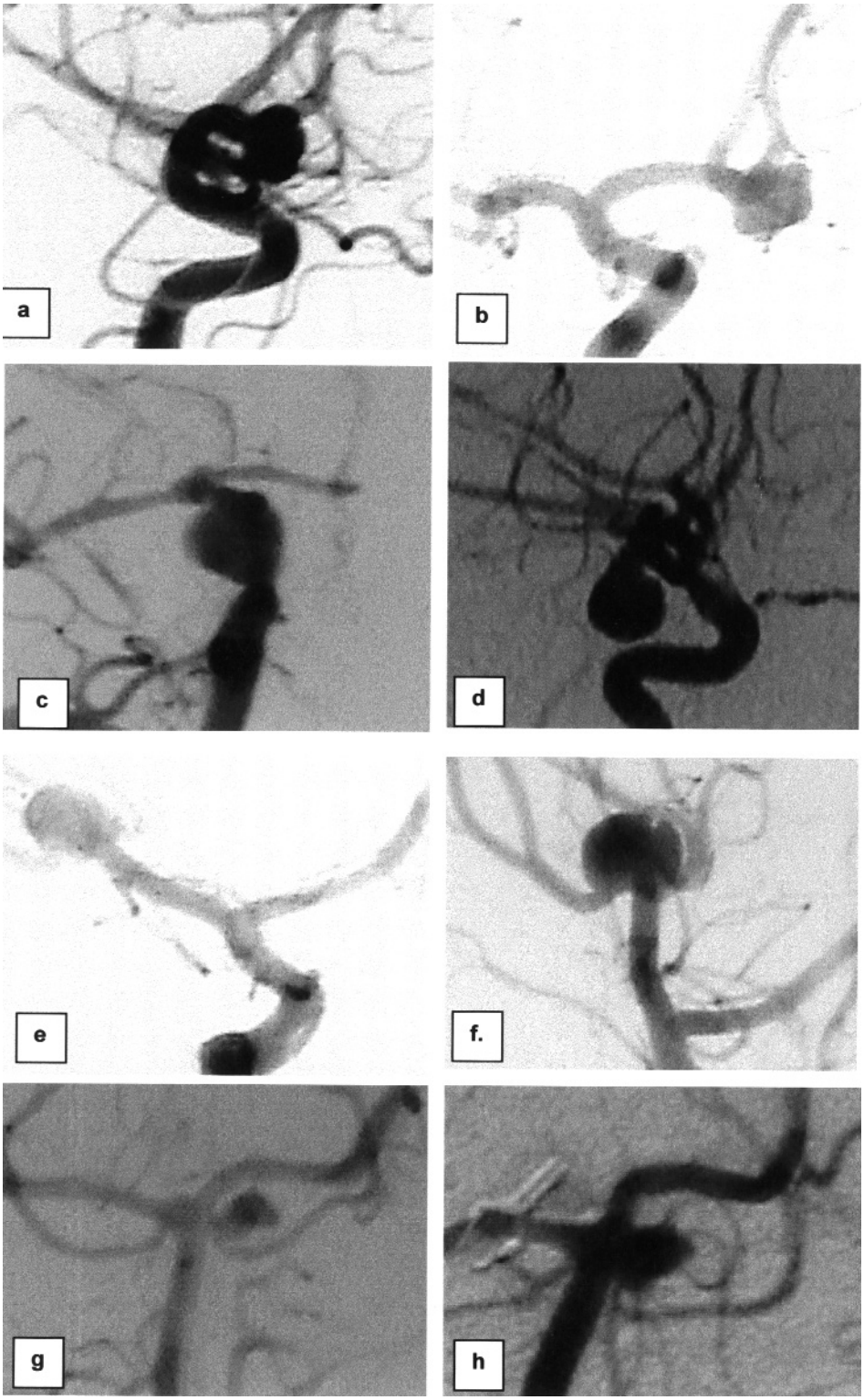

Figure 1 A series of DSA films showing examples of cerebral aneurysms: (a) and (b) anterior communicating artery aneurysms; (c) and (d) internal carotid artery aneurysms; (e) and (f) middle cerebral artery aneurysms; (g) and (h) superior cerebellar artery aneuysms.

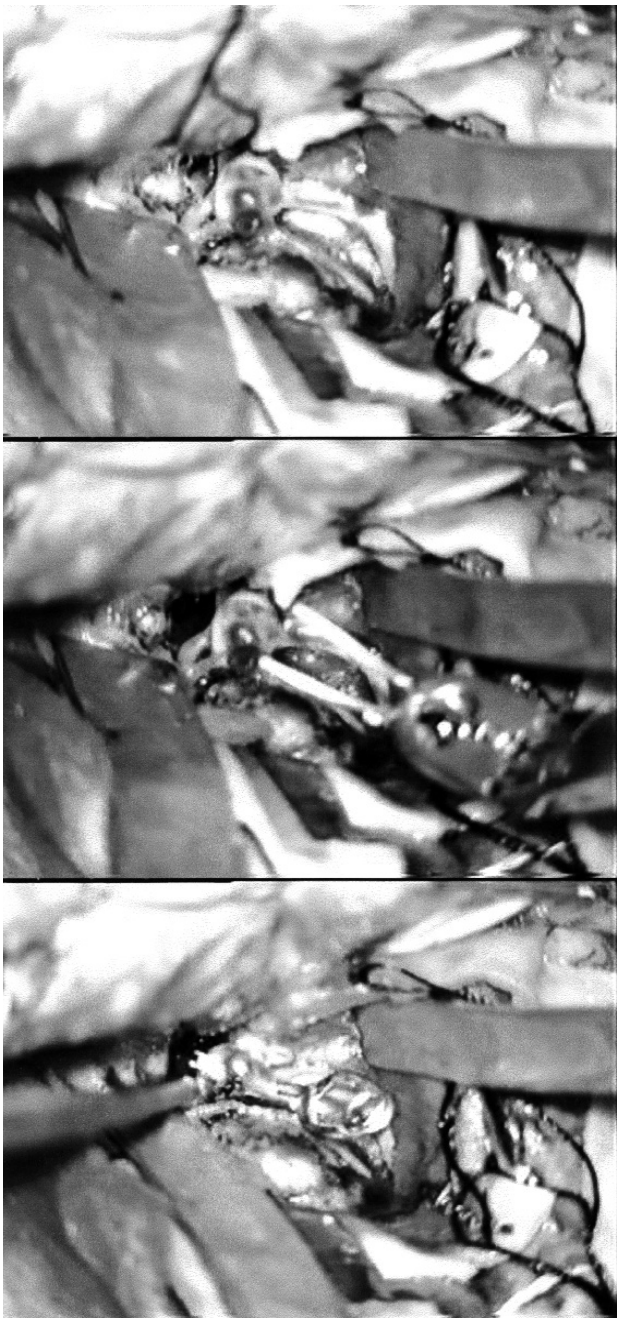

Figure 2 Photographs taken through an operating microscope demonstrating: (a) a middle cerebral artery aneurysm, (b) surgical clip prior to clipping of the aneurysm, and (c) clip across the aneurysm with aneurysm collapsed. See also Figure 3

Endovascular treatment of intracranial aneurysms has gained wide acceptance. This modality of treatment accounts for the majority of cases in some British neurosurgical units. This proportion is likely to rise as coil, catheter and balloon technologies advance and stenting procedures are developed. Early results confirm great success at protecting the patient from re-rupture and avoiding intracranial surgery.[5–7] However, the true long-term picture is awaited and, as such, microsurgery remains the gold standard treatment for benchmarking purposes. Coil impaction and increase in the size of residual aneurysm necks are well recognised. A proportion will require further treatment whilst others are monitored. A late re-bleed rate has yet to be quantified, and as such the significance of coil impaction is uncertain.

Recent evidence has lead to a radical re-consideration on the management of unruptured aneurysms.[8] Many are being managed conservatively and, of those which are obliterated, an endovascular approach is generally favoured. Thus, there has been a reduction in the number of cerebral aneurysms being treated surgically. In addition, there is anecdotal evidence suggesting that many of the aneurysms coming to surgical treatment tend to be at the difficult end of the spectrum. In combination, these factors are limiting exposure to aneurysm surgery during the training period. Since not all aneurysms can be treated by endovascular methods, it is imperative that adequate training continues in vascular neurosurgery.

The aim of this study was to analyse the impact on surgical training of the introduction of endovascular treatment at our unit.

Patients and Method

All patients who had aneurysms treated at Middlesbrough General Hospital between 1 January 1996 and 31 December 1999 were identified. A customised pro forma was designed and data relating to clinical presentation, treatment and complications were collected. Outcomes at discharge and follow-up (approximately 6 months) as assessed by the Glasgow Outcome Score (GOS) were also recorded.[9]

The cerebral angiograms were obtained for assessment of the aneurysms. We devised a scoring system to grade 'ease of clipping' and 'ease of coiling' of aneurysms. For the purposes of this study, the only features assessed were the angiographic morphology/configuration of the aneurysms. The assessment was performed independently by a single neurosurgeon and the interventional neuroradiologist. They were blinded to patient age, grade, co-morbidity, co-existing aneurysms, actual treatment and outcome. Factors that constituted a surgically 'easy' aneurysm (*i.e.* one appropriate for year 4 specialist registrar training) were anterior circulation, common location, non-giant, well-defined neck, and absence of surrounding vessels (Table 1). Using this scale, we were able to make an objective assessment to quantify the effect that endovascular treatment has had on surgical training. It also eliminated any bias that may have reflected periods during the study period when the

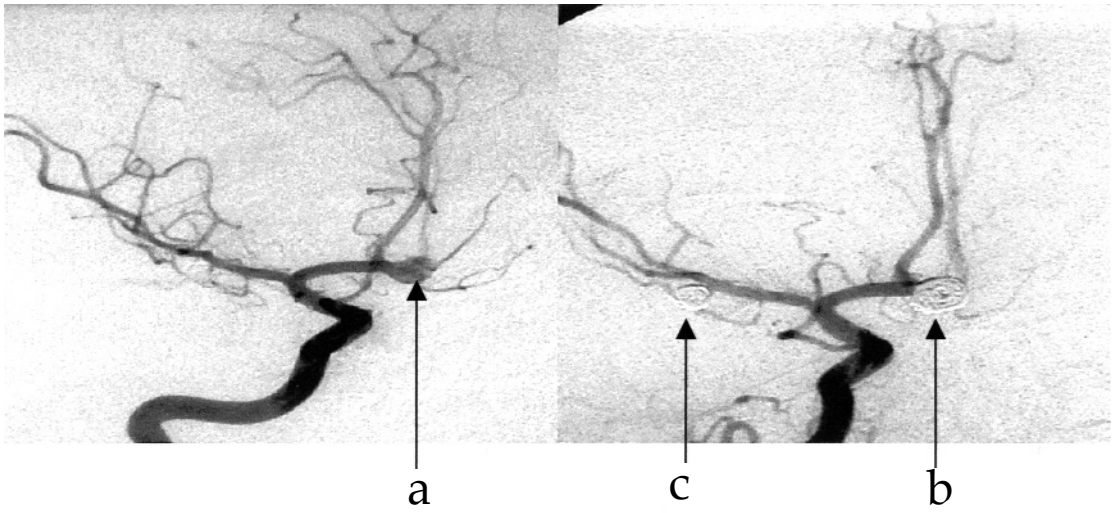

Figure 3 Pre- and post-treatment digital subtraction angiograms confirming occlusion of anterior communicating artery aneurysm: (a) and (b) and previously treated middle cerebral artery aneurysm, (c) by GDC coiling.

Table 1 Classification of ease/difficulty for aneurysm treatment by surgical or endovascular means based on angiogram assessment

Modality	Grade	Definition
Surgical		
	Easy	Common location, minimal branches
	Moderate	Anterior circulation, unclear anatomy (neck and perforator branches)
	Difficult	Posterior circulation, blowout, uncom–mon site, branches arising from sac
Endovascular		
	Easy	Defined neck, good fundus:neck ratio
	Moderate	Coilable but not straightforward
	Difficult	Risk incomplete occulsion, surgery preferable
	Surgical	Impossible to treat endovascularly

incumbent registrars were not senior enough to be performing aneurysm surgery.

We defined appropriate trainee aneurysms as being designated surgically easy and difficult or impossible (*i.e.* surgical) to treat by endovascular methods.

Results

A total of 205 patients were admitted to the unit having suffered a subarachnoid haemorrhage, and underwent definitive treatment. All of these patients were included in the analysis.

This population studied largely conformed with major published series in terms of patient demographics (Table 2) and aneurysm location, but we did note a slight over-representation of middle cerebral artery aneurysms (Fig. 4).[10] The groups were comparable over each of the years studied.

Table 2 Patient demographics over the 4 year study period. The patients from each year are comparable in numbers, age and gender over the study period, and are in keeping with major published seres

Year	1996	1997	1998	1999
Number	59	48	50	48
Age range (years)	10–66	30–78	31–74	24–73
Mean	49	51	51	52
M:F	20:39	17:31	16:34	12:36

Table 3 Number of aneurysms treated by surgery and by endovascular coiling over the 4-year period. Approximately equal numbers of aneurysms have been treated by each method in the last two years of the study

Year	1996	1997	1998	1999
Surgical	58	43	26	28
Endovascular	1	5	24	20
Total	59	48	50	48

Facilities for endovascular treatment were established in the unit in March 1997. One ruptured aneurysm was treated by coiling in 1996 when the interventional neuroradiologist visited the unit. The number of cases being treated by endovascular means has risen rapidly and now approaches parity with surgery (Table 3).

A total of 172 angiograms (87%) were available for analysis. A further 3 had insufficient views to enable assessment for coiling. Approximately 30–40% of aneurysms were classified as easy to clip based on angiogram assessment (Table 4). The series is too small to comment on the apparent reduction in easy aneurysms over time.

Table 4 Aneurysm grading based on angiogram assessment (S - surgical group, E - endovascular group). Formal grading was determined retrospectively and independently by a consultant neurosurgeon (PJK) and a consultant interventional neuroradiologist (JED). Assessment was performed without knowledge of actual treatment, and therefore does not reflect actual treatment

	1996 S	1996 E	1997 S	1997 E	1998 S	1998 E	1999 S	1999 E
Easy	21	11	13	4	13	4	12	5
Moderate	19	15	11	15	19	22	18	8
Difficult	14	9	8	4	15	9	10	9
Surgical		16		9		12		18
Unable to access		3						
Angiograms unavailable	5	5	16	16	3	3	8	8
Total	59	59	48	48	50	50	48	48

Table 5 Analysis of surgically 'easy' aneurysms. All aneurysms considered surically 'easy' i.e. appropriate for SpRs are includedin this tabe. Their endovascular grading is given; actual treatment undertaken is shown in the final two columns. We would advocate endovascular treatment of those aneurysms which are easy or moderate by endovascular means regardless of surgical score. Over 4 years only 17 aneurysms were considered to be surgically easy and endovascularly difficult or impossible (total of columns 'difficult' and 'surgical' shown in bold)

Year	No.	Easy	Mod.	Diff.	Surg.	Unable to access	Clip	Coil
1996	21	7	5	2	6	1	21	0
1997	13	3	6	1	3		12	1
1998	13	3	9		1		8	5
1999	12	2	6		4		6	6

A full-time interventional service cannot be maintained in the unit at present due to having only a single interventional neuroradiologist and restricted anaesthetic support. Despite these restrictions, almost half of the surgically easy aneurysms have been coiled in the last 2 years of the study period. If the service allowed all aneurysms considered to be endovascularly easy or moderate to be coiled, then just 17 aneurysms (of the 172 assessed) would have been available for specialist registrars in the last 4 years (Table 5).

Discussion

Until recently, surgery was the definitive treatment for cerebral aneurysms. Studies have clearly demonstrated the risks associated with harbouring an aneurysm that has already ruptured. Patients are only managed conservatively when the risks of treatment outweigh those of remaining untreated, or if they are a poor grade.

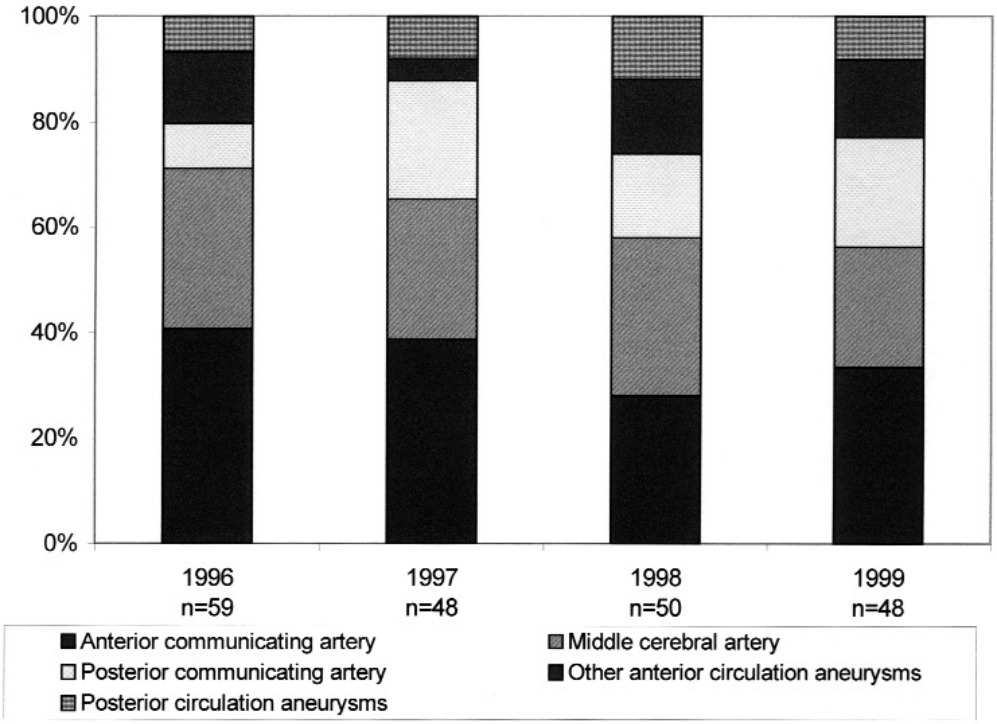

Figure 4 Aneurysm location for each year

The advent of endovascular techniques has changed this pattern of management. This treatment modality has evolved rapidly from the days of parent vessel occlusion and subsequently detachable balloons placed within aneurysm sacs to preserve the parent vessel. The advent of Guglielmi detachable coils has further improved the safety compared to the use of pushable coils. Current emphasis in endovascular research rests with the development of stents and coils which will result in more stable thrombus.[11–15]

Surgery remains the gold standard in cerebral aneurysm treatment. In order for all ruptured aneurysms to be coiled, one would need conclusive evidence (from a prospective randomised trial) that outcome was more favourable from coiling than from surgery (*i.e.* lower procedure-related morbidity and mortality, and satisfactory long-term occlusion rates preventing future re-bleeds). ISAT (the International Subarachnoid Aneurysm Trial) is on-going, and the results are eagerly awaited. ISAT only deals with aneurysms for which it is unknown which modality of treatment is better and, as such, all aneurysms entered must be treatable by either modality. Considering aneurysm location, there is a consensus that aneurysms in the posterior circulation constitute a greater surgical risk.[16,17] Not only is access more difficult, but they only represent 5% of all aneurysms. Endovascular treatment has been demonstrated to be efficacious for dealing with such aneurysms.[18] Some uncertainty remained over aneurysms affecting the tip of the basilar artery. Complete occlusion is often difficult due to: (i) wide necks; (ii) nearby critical vessels which increase the risk of coil prolapse; and (iii) thrombo-embolic phenomena affecting the brain stem. However, despite this, favourable outcomes are seen.[19] The other 'difficult' surgical location is the para-ophthalmic region. By contrast, aneurysms at the bifurcation/ trifurcation of the middle cerebral tend to be difficult to coil due to the presence of branch vessels, and difficulties in accurate assessment of the aneurysm neck.

The aneurysm configuration is an important factor in selection for coiling. A neck of less than 5 mm diameter with fundus:neck ratio of greater than 2 is ideal giving optimal complete occlusion rates.[20] The evolution of 'remodelling techniques' and better coils may increase the range of ideal aneurysms.

Clearly, not all aneurysms are amenable to coiling. In addition, there are increasing cases of aneurysms coming to surgery having had previous coiling.[21,22] This may be due to enlarging residual necks or coil migration. Furthermore, there are cases which are selected for a combined surgical and endovascular approach.[23] All of these cases are more complex than primary clipping. In addition, these are all problems which are likely to increase in the future when the true long-term effect of coiling becomes apparent.[24]

Our data demonstrate the approximate halving of aneurysms reaching surgery. The development of a full-time endovascular service will reduce the number of surgical cases further. The debate over which unruptured aneurysms require treatment continues, and these where possible generally undergo coiling. Overall the number of surgical cases seen by trainees is falling.

Table 6 Modern innovations diminishing exposure in surgical training

Specialty	Modern procedure
Urology	Percutaneous nephrostomy
	Percutaneous shock wave lithotripsy
Vascular/cardiothoracic surgery	Anioplasty
	Embolectomy, thrombolysis
	Stenting

This reduction in numbers is not unique to Middlesbrough. Indeed, it is not a problem restricted to neurosurgery. Other surgical specialties have also found radiologists and physicians developing interventional methods as alternatives to established surgical practices (Table 6). The management of renal stone disease has been transformed by the development of percutaneous short wave lithotripsy (PSWL) and percutaneous nephrostomy. Further examples of loss to the surgical trainee are seen in vascular surgery and cardiothoracic surgery, namely angioplasty, embolectomy, thrombolysis and stenting. Strategies need to be developed to ensure adequate training continues. Simple measures such as sub-specialisation and targeted training could be introduced readily. This would restrict the aneurysms to fewer consultants and their registrars. Registrars would then pass through these vascular firms at an appropriate time in their training. In smaller units, it may be necessary to restrict the number of senior trainees to minimise the dilution of aneurysms per registrar. It may become appropriate for current registrars to undertake vascular fellowships if they were to subspecialise in aneurysm surgery.

Clinical governance has highlighted the issues of audit, evidence-based medicine, and the problems of inadequate peer review. At present, we do not have universal acceptance of endovascular treatment. The results of a class I study are needed before this occurs. In addition, studies looking at outcome show comparable results from surgery and endovascular treatment. Poor grade patients at presentation do worse than good grade patients and so outcomes are dominated by the effect of the haemorrhage rather than the treatment modality. It may be that subtle differences need to be detected to highlight the true benefits of endovascular treatment; outcome scales such as the GOS or the modified Rankin score will not reflect any perceived benefit of endovascular treatment.

Cranial microsurgery is associated with significant complications particularly when considering aneurysm surgery. Endovascular treatment appears to be successful in achieving the short-term objective of protecting the patient from the devastating consequences of a re-bleed. Long term follow-up will be required before we know how effective this approach is compared to surgery for anterior circulation aneurysms in the young patient. Until this information is available, we should ensure that training is tailored to maintain surgeons proficient in the art of cerebral aneurysm surgery.

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