Vascular neurosurgery following the International Subarachnoid Aneurysm Trial: modern practice reflected by subspecialization

Clinical article


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Object. In this paper the authors’ goal was to report on and examine (in the context of a large hospital with good endovascular intervention provisions) the activities of a neurosurgeon with a dedicated vascular interest in the era after the International Subarachnoid Aneurysm Trial in the United Kingdom. They also aimed to establish therapeutic trends and outcomes.

Methods. The authors reviewed the multidisciplinary team activity of 1 neurosurgeon and 2 interventional radiologists during a period of 22 months (2005–2007). They reviewed 281 aneurysm interventions; the majority was used to treat subarachnoid hemorrhage. Data analysis showed a strong preference for endovascular treatment for acute rupture (86.6 vs 13.4%), with a progressively greater role for open microsurgery in the more elective context (57% endovascular vs 43% surgical). They also reviewed 66 interventions for arteriovenous malformations, of which only 6 were surgical. These data are compared against a sample year from 2001 to 2002 (pre–International Subarachnoid Aneurysm Trial), showing comparable rates of surgically treated aneurysms versus endovascularly treated aneurysms, but an increase overall in the number of patients requiring open surgery.

Results. The authors found that excellent outcomes for microsurgical clipping compared with endovascular therapy can be achieved within the current climate. These and previously published data strongly support a continuing role for vascular neurosurgery as a subspecialty in combination with a dedicated endovascular service and a multidisciplinary team.

Conclusions. Despite a trend to prefer coiling for ruptured aneurysms, the authors have shown that there is still a vital role for open surgery in the management of the ruptured and unruptured aneurysm. They consider the remaining role for surgery for arteriovenous malformations within the modern era of endovascular therapy.

Key Words • aneurysm • clipping • coiling • International Subarachnoid Aneurysm Trial • neurovascular surgery

The ISAT has had far-reaching effects on neurovascular surgery.19,21,32 Craniotomy for ruptured intracranial aneurysms has gone from being a staple operation performed by most neurosurgeons to a less common, and perhaps less desirable, procedure reserved for unusual patients or unusual situations.25 Some impressive series have been published of the outcomes in relation to the safety of endovascular treatment of the ruptured aneurysm,43 and the inevitable debate continues over the optimum treatment modality for the unruptured intracranial aneurysm.9,22 Since the publication of ISAT, there has been much debate as to the declining role of the neurosurgeon in the treatment of patients with neurovascular problems.19 The improved outcomes in relation to subspecialization are well documented2,11 and more recently the clinical outcomes in relation to post-ISAT intervention have been reported.7,15,24

One of the recurring themes in commentary on vascular neurosurgery in the modern era is of the importance of multidisciplinary decision making for such patients.6,24 There are a few instances of individual clinicians becoming skilled in open surgical and endovascular treatment modalities; however, this is by far the exception rather than the rule.17 It is not controversial to suggest that patients undergoing treatment of intracranial aneurysms by

Abbreviations used in this paper: AVM = arteriovenous malformation; ISAT = International Subarachnoid Aneurysm Trial; MCA = middle cerebral artery; SAH = subarachnoid hemorrhage; UK = United Kingdom; WFNS = World Federation of Neurosurgical Societies.
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either modality should do so in a large center with expertise in both areas.\textsuperscript{5,9,24} In this context the outcomes for patients with good neurological grades should be excellent.

We report on the post-ISAT surgical workload presented to a dedicated vascular neurosurgeon in the UK, in particular with relation to an experienced endovascular service and a dedicated multidisciplinary team, and review the outcomes of open and endovascular treatment in this context during a 22-month period. We also analyze available data from the same unit for a single year (2001–2002) before publication of the ISAT study and consider the continued role of open surgery in the context of the changing pattern of work, as well as the outcomes from treatments in this context.

\textbf{Methods}

We reviewed the surgical activity of the senior author (C.T.) during a 22-month period (2005–2007). A database of all vascular-specific surgeries was created. Data on the nature of surgery, referral source, indication, and outcome were generated. In the case of patients undergoing craniotomy for aneurysm, specific details in relation to endovascular therapy were also sought: why endovascular treatment was not performed, whether it had been performed previously, and so on. Neurological outcomes were also noted, as well as the timing and results of follow-up angiographic investigations if performed. We also reviewed the nonaneurysmal cranial vascular neurosurgery activity of the senior author.

Over the same period we reviewed the activity of the interventional neurovascular service (T.H. and N.D.). The workload of the service was reviewed with regard to aneurysm and AVM procedures, whether they were performed electively or on an emergency basis, and how many were repeated procedures.

We also reviewed the activity of the department for a given year (2001–2002) in relation purely to aneurysm intervention. The number of endovascular procedures for all intracranial aneurysms was reviewed as well as the number of open operations for aneurysms.

\textbf{Results}

\textit{Recent Open Surgery for Intracranial Aneurysms}

<table>
<thead>
<tr>
<th>Presentation</th>
<th>No. of Aneurysms</th>
</tr>
</thead>
<tbody>
<tr>
<td>acute SAH</td>
<td>26</td>
</tr>
<tr>
<td>incidental finding</td>
<td>8</td>
</tr>
<tr>
<td>unruptured/previous SAH from other aneurysm</td>
<td>4</td>
</tr>
<tr>
<td>previously coiled neck recurrence</td>
<td>3</td>
</tr>
<tr>
<td>previously clipped neck recurrence</td>
<td>1</td>
</tr>
<tr>
<td>acute SAH (rupture of previously coiled aneurysm)</td>
<td>1</td>
</tr>
<tr>
<td>screening (strong family history)</td>
<td>1</td>
</tr>
<tr>
<td>total</td>
<td>44</td>
</tr>
</tbody>
</table>

We have experienced no clinically detectable neurological deficits in the 17 patients who underwent surgery without rupture or in a delayed fashion. Of the 12 patients with Grade I hemorrhage, 11 had no postoperative deficits and the remaining patient experienced moderate mixed expressive and receptive dysphasia following clipping of an uncookable left \( M_1/M_2 \) junctional aneurysm. Of the 6 patients with Grade II SAH, 1 was left with mild cognitive impairment following surgery for an uncookable right MCA aneurysm, and 1 suffered both cognitive impairment and right third nerve palsy following surgery for a
right posterior communicating artery aneurysm. The 2 patients with Grade IV SAH recovered with moderate cognitive impairment in 1 case (second hemorrhage from a pericallosal aneurysm) and right hemiplegia with cognitive impairment (right MCA aneurysm with intraparenchymal hematoma).

Follow-up imaging was available for 29 of 40 patients and was performed between 6 and 18 months (mean 8.1 months). Of these, 10 were followed up with CT angiography and 19 with catheter digital subtraction angiography.

Twenty-six patients were shown to have no remnant and were discharged from radiological observation. One patient was lost to follow-up and 10 await imaging. Two patients had an incomplete result: 1 patient was found to have a neck remnant that was coiled successfully and 1 neck remnant was kept under surveillance.

Recent Open Surgery for Intracranial AVMs

The changing nature of AVM management means that we have performed only 6 AVM surgeries in 5 patients during this time, and the majority of the AVM workload has been managed with endovascular obliteration or radiosurgery. Of these patients, 2 presented with seizures, and 1 patient each presented with an acute hematoma, with benign intracranial hypertension, and following investigation for headaches. All AVMs were excised completely, and 1 patient required a second craniotomy after angiography showed residual AVM. There were no new deficits after these operations; 1 patient suffered persistent preoperative memory and language problems after craniotomy for AVM with hematoma.

Five patients underwent high-flow bypass surgery using the excimer laser-assisted nonocclusive anastomosis technique. Three of these procedures were for terminal carotid artery aneurysms; 2 of these were blocked after treatment of the aneurysm without neurological deficit. One remains patent. One procedure was undertaken to cover excision of a glomus vagale tumor; the bypass was blocked again without deficit. The final patient, who underwent surgery for a Grade I hemorrhage from a complex carotid artery termination aneurysm unsuitable for direct treatment, experienced bypass occlusion shortly following surgery with complete hemispheric infarction and died.

One conventional superficial temporal artery–MCA bypass was performed for M1 stenosis with a good angiographic and clinical result.

Recent Endovascular Treatment of Intracranial Aneurysms

During the same period, 237 intracranial aneurysm embolization procedures were performed (Table 2). Of these, 174 were for acute spontaneous SAH, of which 3 had undergone previous treatment (1 clipped and 2 coiled). Seventeen aneurysms were treated that were asymptomatic at presentation either incidentally during other neurological investigations or following screening for intracranial aneurysm. Sixteen were unruptured presenting with mass effect and 30 were previously treated but recurrent; 3 had been clipped and 27 coiled. Of these 237 procedures, 217 (92%) were considered complete and 20 (8%) were abandoned for technical reasons or vasospasm.

Of the 125 aneurysms (53%) that were completely occluded after a single procedure, 55 were removed from follow-up, 64 were awaiting a further MR angiography at 18 months, and 6 were awaiting review in clinic. Of the 28 aneurysms with neck recurrence, 26 were kept under radiological surveillance, 2 were lost to follow-up, and 1 was discharged because the age of the patient contraindicated further intervention.

Of the 19 with significant recurrence, 2 were referred for open surgery and 17 required a repeated coiling procedure. Of the 17 unsuccessful procedures, 9 cases were treated using a second procedure during the same admission, 6 were referred for open surgery, in 1 the patient died (of a pulmonary embolism), and in 1 the patient refused further treatment. There was 1 rehemorrhage that was successfully treated with repeated embolization. These outcomes are shown in Table 3.

Recent Endovascular Treatment of Intracranial AVMs

Sixty-six embolization procedures were performed to treat cerebral AVMs in 39 different patients, 19 of whom presented with hemorrhage. All procedures were performed with curative intent, and in cases in which embolization failed to achieve complete occlusion, further treatment aimed at occlusion was planned. Complete occlusion was successful in 16 patients after the first attempt, 5 achieved complete occlusion after multiple endovascular procedures, 8 were referred for stereotactic radiosurgery, 6 were referred for open surgery, 3 are still under review, and 1 was lost to follow-up. There were no early (that is, intra procedural) cases of hemorrhage; there was 1 late (delayed) hemorrhage that then was treated with repeated embolization.

Proportion of Aneurysms Treated With Surgery and Endovascular Therapy

Of all aneurysm procedures (surgical and endovascu-

| TABLE 2
| Presentation of aneurysms treated with endovascular embolization |
|---------------------|------------------|
| Presentation        | No. of Aneurysms |
| acute SAH           | 171              |
| incidental finding  | 16               |
| mass effect         | 16               |
| previously coiled neck recurrence | 27 |
| previously clipped neck recurrence | 3 |
| acute SAH (rupture of previously clipped aneurysm) | 1 |
| acute SAH (rupture of previously coiled aneurysm) | 2 |
| screening (strong family history) | 1 |
| total               | 237              |

| TABLE 3
| Outcomes of coil-treated aneurysms at 6 months |
|---------------------|------------------|
| Outcome             | No. of Aneurysms (%)
| complete occlusion  | 125 (53)         |
| mass recurrence     | 28 (12)          |
| significant recurrence | 19 (8) |
| intraop unsuccessful, requiring 2nd op | 17 (7) |
| died, no evidence of rebleed | 16 (7) |
| still awaiting angiography | 21 (9) |
| lost to follow-up   | 11 (5)           |
| total               | 237              |
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...during the studied period, 201 were treated following acute SAH. Of these, 27 (13.4%) were treated with surgery and the remaining 174 (86.6%) were treated endovascularly. Of the 80 aneurysms treated either electively or following presentation without rupture, 17 (21%) were treated surgically and 63 (79%) were treated endovascularly. Of the 30 aneurysms undergoing primary elective treatment, 13 (43%) were treated surgically versus 17 (57%) endovascularly.

**Surgical and Endovascular Activity Before the ISAT Era**

In the 12 months studied before the ISAT publication (October 2002), there were 185 interventions for the treatment of cerebral aneurysms, of which 170 (92%) were endovascular compared with 15 (8%) open procedures. Of the patients treated endovascularly, 137 (74%) were considered to have had a complete procedure.

**Discussion**

Reports of treatment strategy from a collaborative approach in the modern era have shown varying tendencies toward coiling or clipping. Inevitably the pathway adopted will reflect the experience and involvement of the treating clinicians. We are fortunate to have a department with 2 highly involved endovascular specialists such that in the recently studied period, only 1 patient underwent surgery due to lack of availability of endovascular therapy. The modern era of vascular neurosurgery requires not only new techniques, but also the routine availability of these techniques, especially as they are applied to patients undergoing emergency procedures.

Our decision-making process during recent years has become increasingly based on collaboration. All cases of patients who present to the outpatient clinic are discussed by a team including at least 1 endovascular specialist, a neurosurgeon, and a neurologist. Those presenting acutely are always routinely reviewed by both a surgeon and an endovascular radiologist. The technique and the option of nontreatment or surveillance are considered in all patients. This has been widely recognized as a correct approach to the treatment of these patients.

We believe that the results presented here strongly reflect this approach. Our practice has been to be guided strongly by the principles of ISAT and to preferentially treat all ruptured aneurysms by endovascular means. Clearly some aneurysms are not suitable for endovascular therapy, notably those with a high risk of embolic event from coiling or of unavoidable distal occlusion. Aneurysms that are believed to have only a slight chance of good endovascular occlusion from initial treatment offer a different dilemma, and we have started to prefer craniotomy and clipping as a primary treatment in these patients, including those who would be likely to undergo a craniotomy at some point, especially those in good neurological grade. This practice would be supported by recent data finding increased risk of recanalization for aneurysms with poor occlusion from endovascular treatment, large aneurysms, and, interestingly, ruptured aneurysms. Our experiences of early craniotomy (within 72 hours) for the ruptured aneurysm are favorable, and our complication rate in this series is demonstrably low compared with other series of both coiling and clipping. This is clearly influenced strongly by patient selection, and there is a group of patients for whom we still do not have a good early solution, that is, the patient with a poor-grade ruptured aneurysm who is unlikely to have a good endovascular result. An early coiling procedure simply for protective purposes, despite a lower prospect of permanent obliteration, is very reasonable in this patient group. Our practice in this area is still evolving.

The trend for endovascular treatment of aneurysms has grown worldwide to include patients with unruptured as well as ruptured aneurysms. Large series of patients treated with endovascular therapy as first-line treatment have now shown better outcomes in patients suitable for elective endovascular treatment than those treated surgically, with mortality rates of 0.9 versus 2.5%. It should be noted that these results are of intention-to-treat pathways that will inherently bias the endovascular treatment group, rather than randomized patient groups. Although our study contains a much smaller group of patients, our results compare favorably with these data and support a role for experienced neurovascular surgeons within the elective treatment of these patients. Clearly the opportunities presented by a large catchment area to a surgeon with an interest in vascular neurosurgery provide an ample workload, even in a unit in which endovascular therapy is usually the preferred treatment.

Interestingly we have found, if anything, an increase in the surgical workload in comparison with the same unit’s activity in the pre-ISAT era. During the recent period the rate found for a single surgeon was 22 open surgical procedures per year; in the pre-ISAT period it was 15 per year shared among 4 surgeons. We believe that this demonstrates 2 things: 1) changing referral patterns including an increasing number of patients presenting with unruptured aneurysms, and 2) a justified increasing confidence in the outcomes of surgery for those patients with difficult aneurysms unsuitable for definitive endovascular therapy.

Our experience mirrors that of studies from the US in this respect, in which good outcomes have been demonstrated in larger-volume centers, and this strengthens the argument for regional and supraregional coordination of services. The opportunities presented by such centers will only increase and have led to novel treatments recently including endovascular-assisted clipping techniques. In other respects there has been a notable discrepancy between North America and Europe, particularly in the uptake of endovascular therapy, possibly as a result of concerns over the validity of the findings of this study.

Our declining practice in AVM surgery reflects a growing trend toward embolization or radiosurgery for such patients. With experienced endovascular services these patients may be treated, if necessary multiple times, with a low morbidity rate. The decline in open surgery for AVM has been reflected worldwide and is likely to be formalized by the forthcoming ARUBA (A Randomized Trial of Unruptured Brain AVMs) study. All treatment for AVMs is planned on the basis of catheter angiography. As such, patients may be counseled regarding the prospects of complete occlusion with single or multiple
treatments. One patient that proceeded with craniotomy and excision of the AVM did so specifically because of the possibility of incomplete occlusion via endovascular means, and given a Spetzler–Martin Grade I for the AVM itself, surgery was performed uneventfully. We believe that similar to the results for the endovascularly treated aneurysms, the results of the AVM endovascular interventions (no intra procedural complications, no ischemic events, and 1 delayed hemorrhage) justify this treatment strategy.

We have been able to introduce the excimer laser-assisted nonocclusive anastomosis high-flow bypass into the UK for the first time, with the guidance of the pioneers of the procedure. There is clearly a learning curve with the introduction of any new technique; however, we anticipate that increased experience with this surgery will lead to an increase in the supraregional nature of any major neurovascular service providing it, as has been the American experience.

Conclusions

We have reported the surgical activity of a dedicated vascular neurosurgeon in the post-ISAT era, in a unit with a dedicated and experienced interventional neuroradiology department, in contrast to the activity in the pre-ISAT era. The recent evolution of techniques and experience in endovascular therapy has led to the vast proportion of ruptured aneurysms being treated radiologically; however, there is clearly still a vital role for surgery within this patient group, especially in those patients presenting to the outpatient clinic. The future of the specialty will be dictated by ongoing subspecialization, continued technical and technological progress, and the ongoing change in mode of presentation of the patient with neurovascular disease.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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