British Society of Neurological Surgeons

British Society of Neuroradiologists

The International Subarachnoid Aneurysm Trial (ISAT)

and

Neurovascular Services in the UK

Report of a Joint Working Group

September 2003

Summary of Recommendations

1 Coiling and intracranial vascular surgery both have a role in the treatment of people with an aneurysmal subarachnoid haemorrhage (aSAH)

2 Where neurosurgeon and neuroradiologist agree that either treatment would be equally feasible (that is patients who would have been eligible for ISAT), in the light of currently available data, coiling is the treatment of choice.

3 Coiling is the treatment of choice for most posterior circulation aneurysms.

4 In the present state of knowledge, particularly concerning durability, long term clinical and radiological follow-up is essential.

5 All patients with an aSAH should be referred from the local hospital (DGH) to a neuroscience centre where both vascular neurosurgical and endovascular neuroradiological opinions are always available.

6 Neurovascular teams, consisting of at least 2 vascular neurosurgeons and 2 endovascular neuroradiologists, should be formed in each centre or group of centres to ensure that both opinions are always available to all patients wherever they live. Formal arrangements should be in place to cover periods of annual and study leave or sickness. (The European Working Time Directive (EWTD) may mean that greater numbers are required to ensure the continuing availability of specialist staff.)

7 In the foreseeable future it is unlikely that any centre admitting fewer than 150 people with aSAH each year will be able to support a neurovascular team on its own. We recommend that such centres meet with neighbouring centres to look at ways of forming a joint team to share the work while maximising the expertise. (The EWTD could substantially increase the minimum number of patients needed to sustain a team.)

8 We have noted the reduction in the number of neurosurgeons undertaking intracranial vascular surgery and recommend that this process should continue, leading to the concentration of neurovascular surgery in the hands of a number of specialist vascular neurosurgeons. As surgical treatment for aSAH declines, this will ensure that expertise is maintained and that training and development can continue.

9 A good outcome also depends on good assessment and good peri-operative care. Critical care and other facilities, including staffing,

must be adequate to provide necessary peri-operative monitoring and care in all centres providing a neurovascular service.

10 To facilitate this pattern of management all DGHs should have image transfer equipment capable of transmitting CT/MR images of sufficient clarity to allow diagnostic and therapeutic decisions to be made.

11 To allow neighbouring neuroscience centres to share a neurovascular service, all neuroscience centres should be equipped with image transfer equipment capable of receiving and transmitting CT/MR and angiographic images of sufficient clarity to allow diagnostic and treatment decisions to be made.

12 All centres undertaking investigation and treatment of people with aSAH must take part in systematic audit on a regional or national basis.

13 Resource and practical considerations may mean that, in the short term, the proportion of patients undergoing each form of treatment will vary for reasons other than clinical. This is not a long term option: early action should be taken by commissioners and providers of care to identify and overcome such constraints.

14 Any arrangements between neighbouring centres should be sufficiently flexible to take account of future developments and should accommodate the needs of the rest of the service and of training.

15 Training programmes for neurosurgeons and neuroradiologists will change. The SACs and the Royal Colleges should discuss the future shape of training with the responsible Post Graduate Deans, taking into consideration the continuing change in clinical practice, in particular the growth of sub-specialisation in neurosurgery.

16 Although we expect a gradual movement towards these goals, we note that the pace of change in practice has been rapid since ISAT reported. We therefore suggest that commissioners and providers should have plans in place by the end of 2004 and that all people with aSAH should be treated by neurovascular teams meeting the required activity levels by the end of 2005 at the latest.

17 Further information from ISAT and other studies will become available over the next few years. We therefore suggest that our recommendations should be reviewed in the light of any significant new information and in any case not later than Dec 2007.

1. Introduction

1.1 Following the publication of the results of ISAT[1] the British Society of Neurological Surgeons (SBNS) and the British Society of Neuroradiologists (BSNR) jointly commissioned a working group to look at the implications of the trial.

1.2 The group was asked to look at the management of people with aneurysmal subarachnoid haemorrhage (aSAH) and also the organisation of the neurovascular service. The terms of reference are set out in Appendix 1.

1.3 Each of the two societies nominated three of their members to the working group. The chair was not affiliated to either organisation. The group invited the trial organiser (Dr Andy Molyneux) to present the results of ISAT and took additional advice on the interpretation of clinical trials from Prof Peter Rothwell. Membership of the working group is listed in Appendix 2.

1.4 Members of the group were aware of the strong views held by some US and UK clinicians about the significance and/or limitations of the trial and also of the perceived threat to some institutions or centres.

1.5 The working group was asked to complete its work quickly. Two formal meetings were held with additional consultation and discussion by telephone and email. Details of the references for the major articles used in formulating the recommendations are given in Appendix 4.

2. Aneurysmal Subarachnoid Haemorrhage (aSAH)

2.1 aSAH is not common, affecting approximately 6-8/100,000 people each year in the UK[2].

2.2 About half the people die within one month of the event and one third of the survivors remain severely disabled.[3]

2.3 It is estimated that there are 5-6 therapeutic procedures per year per 100,000 population, all of which are performed in Neurosurgical/Neuroscience Units. [4]

2.4 Rebleeding from the aneurysm and ischaemia (loss of arterial blood supply to tissues) are the two common causes of mortality and morbidity in those people who reach the specialist unit.

2.5 The cumulative risk of rebleeding increases with time after the initial event. This leads to pressure for early treatment.

2.6 The causes of delayed ischaemia are not known. Careful monitoring and aggressive treatment in a critical care setting are thought to give the best hope of minimising permanent damage.[5]

2.7 For almost 70 years the standard treatment has been clipping of the aneurysm through an open operation (craniotomy). Initially this carried a very high mortality but over the years improvements in surgical and anaesthetic techniques, together with improved equipment and better peri-operative care have improved outcome.

2.8 During the last 10 years neuroradiologists have been developing a technique of packing aneurysms with platinum coils through a vascular catheter introduced into an artery in the groin. This does not require opening the skull.

2.9 The MRC funded "International Subarachnoid Aneurysm Trial" (ISAT) was undertaken to compare the two forms of treatment.

3. What was known before ISAT?

3.1 In spite of improvements in outcome over the years, many people are left disabled or dependent following aSAH.[3]

3.2 In published studies there is a wide range of quoted surgical outcome with variation between and within centres. Some of this might depend on case mix, availability of resources or colleagues, but it is likely that at least some is related to the skill of the individual operator.[6,7]

3.3 Outcome appears to depend upon

- -surgical experience[8,9]
- -institutional volume of craniotomy for aSAH[10,11]
- -ability to offer both neurosurgical and endovascular treatment[12]
- -ability to offer angioplasty for ischaemia[12]
- -specific neuro intensive care facility[13,14]

3.4 Coiling is the treatment of choice for most posterior circulation aneurysms.[15]

4. ISAT[1]

4.1 An International, multi-centre, randomised trial comparing outcome after surgical treatment (clipping) with outcome after endovascular treatment (coiling). Most Centres were in the UK.

4.2 To be included patients had to have unequivocal evidence of aSAH. In the opinion of the participating neurosurgeon and neuroradiologist either treatment would have been possible and there was no reason to prefer one over the other. Inclusion was only possible if informed consent was given.

4.3 Centres were only permitted to take part in the trial if the radiologist(s) had already performed at least 30 coiling procedures.

4.4 During the period of recruitment 9559 people with aSAH were admitted to participating centres, of these 2143 were entered into the trial. These proved to have been predominantly people in good condition after a bleed from a small (<1cm) anterior circulation aneurysm.

4.5 There was a small difference (0.6 days) in the time from randomisation to treatment: those in the coiling arm of the trial were treated earlier. Although this could be seen to favour that group further calculation suggests that the difference would not influence the conclusion[16].

4.6 Recruitment to the trial was halted on the advice of the data monitoring committee, in May 2002. They had become aware of a significant difference between the two arms of the trial.

4.7 At that time 1594 patients had completed the 12 month evaluation. There was an absolute difference of 6.9% in the number of people with poor outcomes. Coiling was associated with a 22.6% reduction in poor outcome when compared to clipping.

4.8 By August 2003 figures for 2066 patients completing the 12 month evaluation showed the absolute difference widening to 7.8%.

4.9 All centres taking part in the trial had activity levels sufficient to place them in the top quartile of the series quoted above[11]. Outcome in the surgical limb of the trial was in keeping with outcome in published series of neurosurgical treatment of aSAH. Performance of the biggest recruiting centres was similar to that in the other centres.

4.10 Patients entered into the trial will continue to be monitored: further information will accrue. Additional information on the incidence of epilepsy and of cognitive sequelae as well as data on the angiographic appearances before and after treatment, will become available.

4.11 In the relatively short period of follow up so far there is no significant difference in the incidence of further bleeding. However the long term effectiveness of the two forms of treatment cannot yet be compared.

Other Supporting Information

5.1 Other studies have suggested that coiling carries a higher risk of late rebleeding although the absolute risk remains small.[17,18] Continued clinical follow up and monitoring of the anatomical appearance of the aneurysm will be necessary.

5.2 Endovascular techniques have changed and continue to evolve. It will be necessary to look at the impact of each new development on the risk factors for later rebleeding.

5.3 There is no robust evidence on the incidence of rebleeding after clipping to use as a comparison. ISAT will be the first direct comparison.

5.4 The American Society of Interventional and Therapeutic Neuroradiology and the American Society of Neuroradiogy have recently issued a position statement on the ISAT[19] which concludes “that patients with SAH and aneurysm anatomy indicating a high likelihood of success with endovascular therapy should be offered that option”. They also conclude that, on the basis of considerable evidence, patients with ruptured aneurysms should be evaluated and treated in centres offering both neurosurgery and endovascular treatment.

Conclusions

6.1 The difference in outcome at 1 year in the ISAT is real and cannot be ignored.

6.2 Coiling and intracranial vascular surgery both have a role to play in the treatment of aSAH.

6.3 Currently available evidence is imperfect and incomplete. It is unlikely to be bettered in the immediate future.

6.4 There is considerable anxiety among neurosurgeons about the role and durability of coiling in the treatment of aSAH and the impact of any change in management on the viability of smaller centres

6.5 Concerns about durability will be particularly important to those who expect to live longer, ie younger people.

6.6 Continuing follow up will give more information.

6.6 Not all surgeons achieve the same outcome

6.7 Not all centres achieve the same outcome

6.8 The ability to offer a wider range of treatments in a centre with a higher volume of relevant activity confers benefit.

6.9 Peri-operative care is an important component of care. Much of this has traditionally been provided by neurosurgeons and intensivists. Neuroradiologists are unlikely to take over this aspect of care.

6.10 Change is likely to continue.

Practical Considerations

7.1 It is inappropriate and unwise to plan on the basis of single handed practioners.

7.2 The introduction of coiling necessarily reduces the number of people treated by neurosurgery and changes the nature of that surgery. Surgical exposure and experience will decrease at the same time as new techniques are being employed.

7.3 Unruptured aneurysms, arteriovenous malformations and aSAH not subject to surgical or radiological intervention add to the volume of neurovascular activity. The indications for treatment of these conditions will become clearer with time but it is our current judgement that the limiting factor in providing a neurovascular service is likely to be the volume of surgical intervention. It is likely that any additional relevant experience for vascular neurosurgeons would be within the tolerance of our workload projections in Appendix 3.

7.4 If there is a significant reduction in intracranial vascular surgery, newly appointed consultants are not likely to have had broad experience of the techniques. Not everybody will be able to gain the necessary experience during or after formal training, nor would this be appropriate.

7.5 Sub-specialisation is already occurring within neurosurgery. There are neurosurgeons who do not undertake any cranial work and those who no longer treat aSAH.

7.6 Training will become more difficult if the full range of experience is not available in all centres.

7.7 The need to maintain experience and the finite number of people with aSAH restricts the options for providing the service. Appendix 3 illustrates some of the implications of setting standards for levels of activity with varying proportions of coiling and surgery. These calculations and the need to have at least two endovascular neuro radiologists and two vascular neurosurgeons suggest that a team/centre would need to serve a population of at least 2 million to assure quality. If coiling were to increase to 90% then it could be necessary for a neurovascular service to serve a population of at least 6 million if the assumptions in Appendix 3 are realistic.

7.8 The European Working Time Directive might increase the size of population to be served considerably.

7.9 Neuroscience centres will need to give thought to the way in which perioperative care will be provided.

7.10 The need for more neuroradiological time to undertake endovascualar procedures will be reflected in a need for additional appointments and possibly additional angiography equipment.

Impact of ISAT to Date

8.1 Coiling has increased considerably, especially in centres that contributed to the trial

8.2 In several of the larger centres more than 90% of patients with aSAH are now being coiled

8.3 There is a shortage of interventional neuroradiologists

8.4 Cost pressures are apparent in units undertaking high volumes of coiling

8.5 Neurovascular neurosurgeons are concerned about maintenance of standards and training.

8.6 Smaller neurosurgical centres are concerned about their survival if they are unable to treat people with aSAH

Recommendations

In formulating these recommendations we have taken account of the published evidence and of the real concerns of neurosurgeons, neuroradiologists and institutions.

We recognise the limitations of the evidence but do not believe that it is possible (and certainly not wise) to ignore the ISAT result or the very large observational studies from the US.

Although some of the evidence is not as strong as the grade 1 evidence of ISAT, we do believe that it is sufficient for us also to conclude that volume of activity and experience, both individual and institutional, do make a difference.

We acknowledge that Centres in different parts of the UK will be starting at different points and will have different opportunities to move forward.

9.1 Coiling and intracranial vascular surgery both have a role in the treatment of people with aSAH

9.2 Where neurosurgeon and neuroradiologist agree that either treatment would be equally feasible (that is patients who would have been eligible for ISAT), in the light of currently available data, coiling is the treatment of choice.

9.3 Coiling is the treatment of choice for most posterior circulation aneurysms.

9.4 In the present state of knowledge, particularly concerning durability, long term clinical and radiological follow-up is essential.

Practical implications for the service are:

9.5 All patients with an aSAH should be referred from the local hospital (DGH) to a neuroscience centre where both vascular neurosurgical and endovascular neuroradiological opinions are always available.

9.6 Neurovascular teams consisting of at least 2 vascular neurosurgeons and 2 endovascular neuroradiologists, should be formed in each centre or group of centres to ensure that both opinions are always available to all patients wherever they live. Formal arrangements should be in place to cover periods of annual and study leave or sickness. (The European Working Time Directive (EWTD) may mean that greater numbers are required to ensure the continuing availability of specialist staff.)

9.7 In the foreseeable future it is unlikely that any centre admitting fewer than 150 people with aSAH each year will be able to support a neurovascular team on its own. We recommend that such centres meet with neighbouring centres to look at ways of forming a joint team to share the work while maximising the expertise. (The EWTD could substantially increase the minimum number of patients needed to support a team.)

9.8 We have noted the reduction in the number of neurosurgeons undertaking intracranial vascular surgery and recommend that this process should continue, leading to the concentration of neurovascular surgery in the hands of a number of specialist vascular neurosurgeons. As surgical treatment for aSAH declines, this will ensure that expertise is maintained and that training and development can continue.

9.9 A good outcome also depends on good assessment and good peri-operative care. Critical care and other facilities, including staffing, must be adequate to provide necessary peri-operative monitoring and care in all centres providing a neurovascular service.

9.10 To facilitate this pattern of management all DGHs should have image transfer equipment capable of transmitting CT/MR images of sufficient clarity to allow diagnostic and therapeutic decisions to be made.

9.11 To allow neighbouring neuroscience centres to share a neurovascular service, all neuroscience centres should be equipped with image transfer equipment capable of receiving and transmitting CT/MR and angiographic images of sufficient clarity to allow diagnostic and treatment decisions to be made.

9.12 All centres undertaking investigation and treatment of people with aSAH must take part in systematic audit on a regional or national basis.

9.13 Resource and practical considerations may mean that in the short term the proportion of patients undergoing each form of treatment will vary for reasons other than clinical. This is not a long term option: early action should

be taken by commissioners and providers of care to identify and overcome such constraints.

9.14 Any arrangements between neighbouring centres should be sufficiently flexible to take account of future developments and should accommodate the needs of the rest of the service and of training.

9.15 Training programmes for neurosurgeons and neuroradiologists will change. The SACs and the Royal Colleges should discuss the future shape of training with the responsible Post Graduate Deans, taking into consideration the continuing change in clinical practice, in particular the growth of sub-specialisation in neurosurgery.

9.16 Although we expect a gradual movement towards these goals, we note that the pace of change in practice has been rapid since ISAT reported. We therefore suggest that commissioners and providers should have plans in place by the end of 2004 and that all people with aSAH should be treated by neurovascular teams meeting the required activity levels by the end of 2005 at the latest.

9.17 Further information from ISAT and other studies will become available over the next few years. We therefore suggest that our recommendations should be reviewed in the light of any significant new information and in any case not later than Dec 2007.

Appendix 1

Terms of Reference

Short-life Working Group on Neurovascular Services

Convened at the request of the Society of British Neurological Surgeons & the British Society of Neuroradiologists

Terms of Reference

Working group on future of Neurovascular services with specific reference to the future pattern and planning of services for patients with ruptured intracranial aneurysms.

1. In the light of the publication of the results of the ISAT and other published information regarding the management of patients with ruptured intracranial aneurysms, to advise the SBNS & the BSNR on future patterns of care that are appropriate for these patients in the UK.

2. To advise a planned consensus conference on Neurovascular services of the best evidence and recommendations for management and patterns of care for this patient population.

3. To disseminate the expert advice, through the societies to Health Care commissioners, (including Primary Care Trusts) and Neuroscience Centres.

4. To draw attention to the implications for the training of neurosurgeons and neuroradiologists of any proposed changes to service provision.

Appendix 2

Members of the Working Party

Dr Andrew Clifton	BSNR	London
Dr Anil Gholkar	BSNR	Newcastle
Mr Richard Kerr	SBNS	Oxford
Mr Peter Kirkpatrick	SBNS	Cambridge
Mr Richard Nelson	SBNS	Bristol
Dr Philip White	BSNR	Edinburgh
Dr Ian Williams	Chair	

Dr Andy Molyneux (ISAT) attended one meeting to present and update the ISAT results.

Prof Peter Rothwell (Oxford) attended one meeting to give advice on the interpretation of clinical trials.

Appendix 3

Population Size and Activity Levels

The working group is not in a position to define or dictate the number of procedures required to ensure training or maintenance of expertise in vascular neurosurgery or interventional neuroradiology. We are, however able to point out the implications of a variety of courses of action and to make recommendations on that basis. Assumptions have had to be made but the working group believes that their recommendations are conservative.

The working group has noted the BSNR recommendations of activity levels for training in endovascular techniques and for institutions undertaking training[20].

- There is variation in the quoted incidence and the number of procedures for aSAH per 100,000 population. The quoted figures of 5-6 procedures are close to the generally quoted incidence for aSAH of 6-8 and are thus unlikely to be under-estimates.

- We do not believe it wise or good practice to employ single handed specialists in any specialty. We therefore consider the minimum size of a team to be 2 vascular neurosurgeons and 2 interventional neuroradiologists. Coiling is likely to be more frequent than surgery thus a team including 2 neurosurgeons might well have more then 2 neuroradiologists.

- We have not been able to find publications that identify the minimum number of patients with aSAH to be managed, nor of clipping procedures to be undertaken, to train or maintain expertise. Given the likely reduction in clipping, the need for training, and the likelihood that some of the surgical procedures will be more complex or novel, we do believe that there is a level of activity below which outcome and training will suffer.

- We note that in the first edition of Safe Neurosurgery the SBNS recommended that a neurosurgeon should manage 25 patients with aSAH each year, but found no supporting references. In other areas of neurosurgery (eg acoustic neuroma) considerably larger numbers have been shown to lead to improvement in outcome.

- Over the next 5-10 years many of the neurosurgeons with a large experience of operating on aSAH will retire. Their successors will not have had the same training or experience. In looking for a likely activity threshold for vascular neurosurgeons we have taken these factors into account.

- For experienced neurosurgeons we suggest that a continuing level of at least 15 intracranial vascular surgery procedures for aSAH each year,

including those undertaken by a trainee under supervision, will not be seen to be unreasonable. We expect that this level to rise as the experienced neurosurgeons retire and neurovascular teams develop. Careful audit might help determine the appropriate level although numbers are likely to be small.

- For endovascular neuroradiology the situation is a little clearer. ISAT insisted that all participating radiologists had undertaken at least 30 procedures prior to the trial. The Royal College of Radiology states that trainees should have participated in at least 80 procedures during their training (generally lasting 1 year, sometimes 2 years), in some of which they must have been the main operator. In order to accommodate these requirements we suggest that an interventional neuroradiologist should perform 40 intracranial embolisation procedures each year, most of which will be for aneurysms.

- Coiling rates in the UK vary. Based on the ISAT results and the advice that coiling is the treatment of choice for most posterior circulation aneurysms it is reasonable to anticipate that 75% of patients with aSAH would be coiled if there were no logistical constraint. We believe it right to plan for these levels of coiling to be achieved over the next 3 years, but accept that in the short term the rate will vary between 50-90%. The table shows the implications of such coiling rates.

Assuming 50 procedures/million population

% Coiled	Coils per million	"Clips" per million	Pop'n for 30 clips
50	25	25	1.2m
70	35	15	2m
80	40	10	3m
90	45	5	6m

"Clips" includes other intracranial vascular surgical procedures for aSAH

- At all but the lowest coiling rates it is likely that the limiting factors will be the number of trained interventional radiologists (rather than activity levels per neuroradiologist) and the activity level required to maintain and develop vascular neurosurgical expertise.

- If our suggested goal of establishing neurovascular teams with at least 2 vascular neurosurgeons is accepted, and the suggested minimum activity level for each surgeon is 15 intracranial vascular procedures for aSAH each year, then a team will need to perform 30 such procedures each year.

- If 90% of patients have coiling, as is current practice in some centres, it would require a population of 5-6 million to support these levels. Even if the required surgical activity were to be reduced to 10 procedures per surgeon per year the population would still have to be 3.5-4 million. Centres with such high rates of coiling will need to find ways of working with other centres if surgical expertise is not to be lost.

- Even at the 75% coiling that we anticipate, a required surgical activity rate of 15 procedures per surgeon per year could only be supported by a population of 2-2.5 million. Such a population would be expected to give rise to 120 procedures for aSAH and about 150 people with aSAH each year.

- Some patients require urgent treatment. The requirements of the European Working Time Directive and new contract arrangements could make it impossible to provide a service throughout the year with only 2 neurosurgeons or 2 neuroradiologists. If larger teams are required, larger numbers of procedures will be needed to maintain expertise. Hence there will be fewer teams serving larger populations.

- Whichever levels of activity are taken it is unlikely that a population of less than 2 million could sustain even the smallest team.

Although there are many variables we conclude that it would not be wise to plan for neurovascular teams <u>treating</u> fewer than 120 patients with aSAH each year after 2005/6.

Appendix 4

References

1. International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet 2002; **360:** 1267-1274.

2. Linn FHH, RinkelGJE, Algra A et al. Incidence of Subarachnoid Haemorrhage. Role of Region, Year, and Rate of Computed Tomography: A Meta-analysis. Stroke 1996; **27:** 625-629.

3. van Gijn J and Rinkel GJE. Subarachnoid haemorrhage: diagnosis, causes and management. Brain 2001; **124:** 249-278.

4. Nelson R. National OPCS4 Statistics. Personal Communication.

5. Cesarini KG, Hardemark H-G and Persson L. Improved survival after aneurysmal subarachnoid haemorrhage: a review of case management during a 12-year period. J Neurosurg 1999; **90:** 664-672.

6. Kassell NF, Torner JC, Haley EC et al. The International Study on the Timing of Aneurysm Surgery. Part 1: Overall management results. J Neurosurg 1990; **73:** 18-36.

7. Kirkpatrick PJ, Kirollos RW, Higgins N et al. Lessons to be learnt from the International Subarachnoid Haemorrhage Trial (ISAT). Br J Neurosurg 2003; **17:** 5-7.

8. Maurice-Williams RS and Kitchen ND. Ruptured intracranial aneurysms—learning from experience. Br J Neurosurg 1994; **8:** 519-527.

9. van Lindert EJ, Bocher-Schwartz HG and Perneczky A. The influence of surgical experience on the rate of intraoperative rupture and its influence on aneurysm treatment outcome. Surg Neurol 2001; **56:** 151-156.

10. Solomon RA, Mayer SA and Tarmey JJ. Relationship Between the Volume of Craniotomies for Cerebral Aneurysm Performed at New York State Hospitals and In-Hospital Mortality. Stroke 1996; **27:** 13-17.

11. Bardach NS, Zhao S, Gress DR et al. Association between Subarachnoid Hemorrhage Outcomes and Number of Cases Treated at California Hospitals. Stroke 2002; **33:** 1851-1856.

12. Johnston SC. Effect of Endovascular Services and Hospital Volume on Cerebral Aneurysm Treatment Outcomes. Stroke 2000; **31:** 111-117.

13. Johansson M, Cesarini KG, Contant CF et al. Changes in Intervention and Outcome in Elderly Patients With Subarachnoid Hemorrhage. Stroke 2001; **32:** 2845-2849.

14. Diringer MN and Edwards DF. Admission to a neurologic/neurosurgical intensive care unit is associated with reduced mortality rate after intracerebral hemorrhage. Crit Care Med 2001; **29:** 692-693.

15. Lempert TE, Malek AM, Halbach vanV et al. Endovascular Treatment of Ruptured Posterior Circulation Cerebral Aneurysms. Stroke 2000; **31:** 100-110.

16. van den Berg R, Rinkel GJE and Vandertop WP. Treatment of ruptured intracranial aneurysms: implications of the ISAT on clipping versus coiling. Eur J Radiol. 2003; 46: 172-177.

17. Murayama Y, Nien YL, Duckwiler G et al. Guglielmi detachable coil embolization of cerebral aneurysms: 11 years experience. J Neurosurg 2003; **98:** 959-966.

18. Raymond J, Guilbert F, Weill A et al. Long-Term Angiographic Recurrences After Selective Endovascular Treatment of Aneurysms With Detachable Coils. Stroke 2003; **34:** 1398-1403.

19. The International Subarachnoid Aneurysm Trial (ISAT): A Position Statement from the Executive Committee of the American Society of Interventional and Therapeutic Neuroradiology and the American Society of Neuroradiology. Am J Neuroradiol. 2003; **24:** 1404-1408.

20. Education Board of the Faculty of Clinical Radiology, The Royal College of Radiologists. “Structured Training in Clinical Radiology”. 2000. Appendix: Curricula for Subspecialty Training –Neuroradiology pp 12-14.