Interdisciplinary Neurosurgery 17 (2019) 124–128

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery

journal homepage: www.elsevier.com/locate/inat

Technical Notes & Surgical Techniques

To clip or coil? Proposal of individual decision making

Rajan Kumar Sharma (M.S.)[a,b,*], Yasuhiro Yamada (M.D., Ph.D.)[b], Tsukasa Kawase (M.D., Ph.D.)[b], Yoko Kato (M.D., Ph.D.)[b]

[a] Department of Neurosurgery, National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal
[b] Department of Neurosurgery, Fujita Health University, Banbuntane Hotokukai Hospital, Nagoya, Japan

ARTICLE INFO

Keywords:
Intracranial aneurysm
Endovascular coiling
Neurosurgical clipping
Unruptured intracranial aneurysms
Ruptured intracranial aneurysm
Subarachnoid hemorrhage
ISAT

ABSTRACT

Background: Once the decision is made to treat the intracranial aneurysm, we should consider between two competing treatment options; open surgery or endovascular therapy. The rationale underlying the choice of treatment modality is usually unclear, as there is little good quality evidence available.
Methods: We discuss here the patient, risk factors and the aneurysm related factors for decision making in management of intracranial aneurysm between endovascular and microsurgical modalities of management.
Results: The relevance of age of patient, modifiable and nonmodifiable risk actors, family history, rupture status of aneurysm, aneurysm related factors like morphology of aneurysm and multiplicity are discussed here. Perceived differences in efficacy and safety of the two different treatment approaches are commonly used in an attempt to justify treatment choices. Difficulties with treatment selection and case to case management plan should be considered.
Conclusion: Properly designed and randomized controlled trials need to be done to address these issues for choosing best management to the patient and definitive guidelines must be made to solve this confusion.

1. Introduction

There is great debate going on for management of Intracranial Aneurysms (IA). Neurosurgeons feel microsurgical clipping holds better place than endovascular management due to its lower rate of recurrence and rebleeding whereas Interventionist feel endovascular management is safe and has less morbidity and mortality compared to former. Human decision making in the presence of uncertainty is a complex, poorly understood process [1]. Yet, “humans are condemned to choice and action”. We should keep “patient first” in mind during management and give the best management to the patient [2]. Surgeons confronted with a patient harboring an aneurysm are inclined to favor clipping, and interventionists coiling. The choice can be even more ambiguous for cross-trained endovascular neurosurgeons. In this article we will discuss various aspects of patient and aneurysm factors in the modalities of intracranial aneurysm management and try to justify superiority of one over the other.

2. Risk factors

2.1. Cigarette smoking

It is seen that cigarette smoking increases chance of subarachnoid hemorrhage in patient with cerebral aneurysms [3–5]. Smokers experienced SAH at a younger age and had a greater number of comorbidities compared with nonsmokers, highlighting the negative ramifications of cigarette smoking among patients with cerebral aneurysms [6–8].

2.2. Hypertension

HTN is another risk factor for SAH. In long term there is no role in aneurysm formation and growth but it has been found that patients taking antihypertensive drugs have decreased chance of aneurysm formation compared to noncompliant patients. History of hypertension

Abbreviations: SAH, subarachnoid hemorrhage; EC, endovascular coiling; IA, intracranial aneurysm; ISAT, the International Subarachnoid Aneurysm Trial; RIAs, ruptured intracranial aneurysms; CFD, computational fluid dynamics; RR, relative risk; OR, odds ratio; CN, cranial nerves; CSF, cerebrospinal fluid

* Corresponding author at: Department of Neurosurgery, National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal.
E-mail address: rajanktm58@gmail.com (R.K. Sharma).

https://doi.org/10.1016/j.inat.2019.04.001
Received 7 January 2019; Received in revised form 6 April 2019; Accepted 7 April 2019

as a risk factor for SAH (RR, 2.5; OR, 2.6) seems to be less crucial than for other stroke subtypes [9,10]. The prevalence of hypertension among SAH patients (20–45%) is somewhat higher than in the general population; after adjustment for age, gender, cigarette smoking and alcohol consumption, history of hypertension has not been shown to significantly increase the risk for SAH, as demonstrated in two case-control studies [11,12].

2.3. Alcohol use

The role of alcohol as a risk factor for SAH has not been as well established. Several cohort (RR > 150 g/week, 2.1) and case-control (OR > 150 g/week, 1.5) studies have shown that excessive alcohol consumption increases the risk for SAH in both men and women, independent of cigarette smoking, age, and history of hypertension [4–8]. Ruigrok et al. [13], drinking > 300 g/week of alcohol attributed to 20% of instances of SAH in the population, and drinking 100–299 g/week accounted for 11% of cases of SAH [11,13].

3. Patients factors

3.1. Rupture status

Microsurgical management of ruptured intracranial aneurysm (RIAs) is more difficult than unruptured as the dome is more fragile and dissection is challenging due to brain edema and/or hematoma [14,15]. So, the tendency to do emergency surgery is more and if the time has lapsed then microsurgical clipping is not done immediately due to vasospasm or edema [14]. Withholding surgery has a great threat of rebleeding. Whereas there is no constrain for the endovascular management as there is no difference in rupture status of aneurysm. It is seen that there is more risk of hemorrhagic complications, recurrence in ruptured cases and tendency to undercoil remains. So, if possible early clipping should be done [15–20].

3.2. Age

According to ISAT when young patients are treated with endovascular management, they have less morbidity and mortality but in the long run have higher recurrence and rebleeding rates. So, Microsurgical management holds better durability compared to endovascular [21,22]. Both clipping and coiling are associated with worse outcomes in old patients as compared to young patients, in both ruptured and unruptured aneurysms. The common-sense practice of sending older patients for “minimally-invasive” coiling, remains unfounded. From an endovascular perspective, older patients have more tortuous vascular anatomy, a higher relative burden of atheroma, and there is ample material to suggest that the elderly tolerate coiling, as well as clipping, poorly as compared to younger patients [18]. In a study done at our center for management of unruptured intracranial aneurysm in elderly > 75 years we found that Hypertension and Diabetes mellitus, posterior circulation aneurysms are poor prognostic factors for surgical management in the elderly. So, co-morbidities in elderly patient with posterior circulation aneurysms we should consider endovascular coiling (EC).

3.3. Mass effect

It is believed that aneurysm deflation following clipping lead to more rapid resolution of the mass effect but endovascular management feels that volume occupied by the coil is small fraction of total aneurysmal volume so there is nonsignificant increase in size of aneurysm due to fresh thrombus followed by volume reduction and aneurysm contraction [23,24]. Endovascular management feels that clipping can render an otherwise transient neurological deficit permanent [25].

4. Aneurysm related factors

4.1. Small aneurysms

Surgically small aneurysms are simple to treat so long as there is sufficient tissue to hold the clip. Unruptured aneurysms dissections are relatively easy but difficulty can arise when there is premature or intraoperative rupture [26]. Small aneurysms, compared to larger ones, are also more difficult to embolize, as there is a smaller margin for error with microcatheter placement, and the forces applied by the coil exiting into the aneurysm are distributed across a smaller surface area, increasing the risk of perforation, particularly in recently ruptured lesions [27,28].

4.2. Large aneurysms

Large aneurysms are difficult to treat both via endovascular and microsurgical approaches [29]. Large aneurysm are difficult to treat surgically and sometimes other modalities like complex clip configuration, Surgical bypass, Aneurysmorraphy needs to be done [30]. For endovascular management of large aneurysm it is easy to catheterize the microcatheter but the challenge of durable occlusion remains [31]. Newer advancements in endovascular techniques to treat such aneurysm like flow diverter and stents may be used, but with added risks of acute or delayed obstruction, hemorrhagic risk of dual antiplatelet and a persistent threat of rupture of lesion [32].

4.3. Location

Standard pterional craniotomy is done for the microsurgical clipping but in some anterior clinoidectomy must be done for ophthalmic artery aneurysms or paraclinoidal aneurysm and a far lateral approach must be used for the vertebrobasilar junction aneurysms [33]. Despite this there is increase exposure related morbidity due to CN manipulation, more extensive tissue dissection and risk of post op CSF leak which is not there in endovascular management. Therefore, posteriorly located aneurysms endovascular managements holds the upper hand [34]. Distal lesions like pericallosal artery aneurysm endovascular procedure has high chance of perforation or incomplete occlusion [35].

4.4. Multiplicity

Presence of the multiple aneurysms makes microsurgical management difficult due to the need for multiple craniotomies. In this setting endovascular procedures remains efficient [36].

4.5. Aneurysm shape and wall thickness

4.5.1. Wide neck aneurysm

When the aneurysm neck is wide and dome: neck ratio is < 1.5 clipping is more favorable then coiling [37]. Endovascular techniques employing stents may be used in this setting, but there is risk of coil herniation into the parent vessel, increase risk of major hemorrhage due to dual antiplatelet therapy (1–2%) and increase thromboembolic risk [38,39].

4.5.2. Large aneurysm and large or essential branch arising from the neck of aneurysm

This condition is difficult to treat by microsurgical clipping. If such condition arises then endovascular management can be opted to decrease the morbidity due to unnecessarily clipping the essential branch or perforators. Still with the endovascular management the risk of under size management and risk of recurrence persists [37,40–43].

4.5.3. Calcified wall

When the wall of aneurysm is calcified microsurgical clipping

becomes technically difficult. In these patient's endovascular management can be considered [41,42].

4.5.4. Intraaneurysmal thrombus

There is a big debate on this as there is risk of emboli both in endovascular and microsurgical clipping. So, selection of procedure must be done with caution as endovascular procedure done in these patients have high chances of under management and this carries high chance of recurrence. Microsurgical clipping holds better if meticulous dissection is done to prevent embolization during dissection [43].

4.5.5. Role of computational fluid dynamics

We still do not have clear demarcation regarding whether low wall shear stress (WSS) or high WSS contributes to aneurysm formation. Few studies have been done to prove efficacy of CFD on management plan of cerebral aneurysm. Meng et al. proposed that high WSS correlates with Type 1aneurysm formation, i.e., small and transparent aneurysms, whereas low WSS contributed to Type 2 aneurysm formation, i.e., thick walled atherosclerotic type [44]. Cebral et al. reported that ruptured aneurysms have higher WSS compared with unruptured aneurysms [45]. Xiang et al. have proposed that lower WSS contributes to rupture of aneurysm [46]. Yoichi et al. proposed that lower shear stress is associated with increased risk of rupture [47]. In study, done in our center Maruf Matmusaev et al. [48] found out that 9 out of 10 cases with low WSS had thinning of the vessel wall. One aneurysm had a bleb. In 90% of cases, they revealed that thinning of the aneurysmal wall during operation which is a predictor for future rupture. So, we can propose that CFD adjunct the microsurgery assist on choosing adequate microsurgical tactic taking into account predicted risk of aneurysm rupture and those in verge of impending rupture can be dealt with microsurgical better and CFD is equally important in endovascular management also to plan treatment as Hemodynamic indices calculated by using computational fluid dynamics techniques, have close correlation with Flow-diverter treatment outcome.

4.5.6. Molecular biology of aneurysm

Formation of cerebral aneurysm occur due to the excessive hemodynamic stress to the intracranial arterial wall bifurcation. Hemodynamic stress, inflammatory reaction by activated macrophages and vascular smooth muscle death is crucial for formation of cerebral aneurysm. If there are macrophages in the wall then we can consider those patients who are symptomatic unruptured aneurysms as ruptured ones and to manage accordingly on priority basis. But this is still in experimental stage and helps us in proposing management to patient as it is seen when there is impending rupture or ruptured there is high chance of under management and high recurrence with endovascular then surgical [49].

5. Decision making

It is always a question of doubt whether to post patient for Microsurgical treatment or Endovascular management. If an old patient comes with large intracranial aneurysm, we cannot address saying that surgery would give better outcome if patient were young and neither we can justify saying that Endovascular management would be favorable and durable if aneurysm is smaller. We need to give best available management to the patient with due care of less morbidity and mortality. So, going for Microsurgical clipping or endovascular coiling should not be the issue in the management rather it should be choosing one treatment which gives the patient maximum benefit with least complications. Aneurysm size and location also dictate intervention, with middle cerebral artery aneurysms treated with clipping having better patient outcomes than with coiling in elderly patients [50–54].

We have addressed various literatures regarding this and have found that some points can be taken in account which helps in decision making and allowing to choose the best treatment with background of evidence-based management and have placed in tabulated form (Tables 1–3).

Table 1
Indication of Microsurgical Clipping or Endovascular Coiling.

		Microsurgical	Endovascular
Age		Young	> 70 years
Intracranial hematoma		Present	Absent
Aneurysm specific factors	Location	MCA Pericallosal	Posterior location
	Neck	Wide neck	Small

Table 2
For clipping and against coiling.

Age		< 50 years	Hauck et al.	2008
		< 70 years	Soloman et al.	1994
		Young age	Komotar et al.	2008
Wide neck			Lot et al.	1999
			Gerlach et al.	2007
Size		> 4 mm	Regli et al.	1999
		> 4 mm	Agakhani et al.	2008
		> 10 mm	Lot et al.	1999
Ratio	Neck: Dome	1.3	Lot et al.	1999
	Dome: Neck	< 1.5	Regli et al.	1999
		< 2.5	Agakhani et al.	2008
Inadequate endovascular access			Regli et al.	2002
Intraluminar thrombus			Regli et al.	1999
Arterial branch occlusion			Regli et al.	2002
			Raftopulos et al.	2003
Complete occlusion unlikely			Raftopulos et al.	2003
			Gerlach et al.	2007
			Seifert et al.	2008
Atheromatosis			Raftopulos et al.	2003
Fibromuscular dysplasia			Raftopulos et al.	2003
MCA aneurysms			Raftopulos et al.	2003
Stent implantation or balloon remodelling			Gerlach et al.	2007
			Seifert et al.	2008

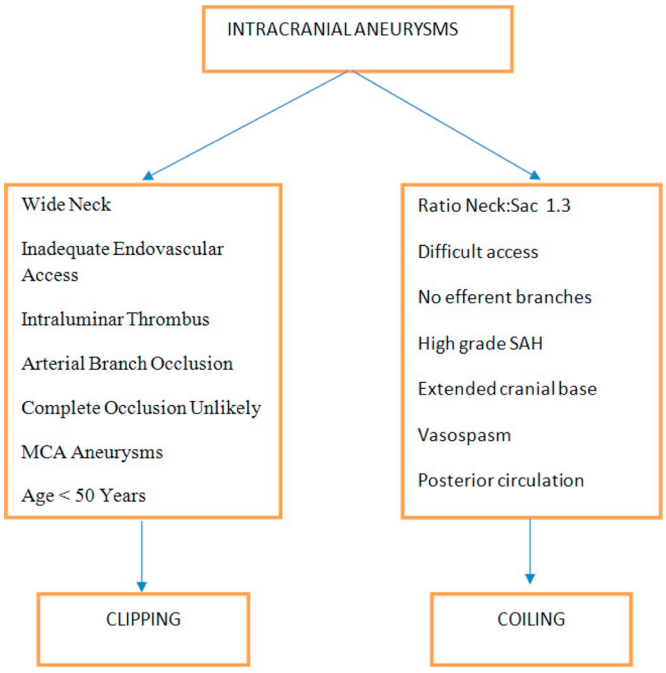

Table 3
For coiling and against clipping.

Ratio		Raftopulos et al.	2008
Neck: Sac	1.3		
Age	> 60 years	Gerlach et al.	2007
	–	Seifert et al.	2008
		Ogilvy and carter et al.	2003
Difficult access		Ogilvy and carter et al.	2003
		Gerlach et al.	2007
		Seifert et al.	2008
No efferent branches		Gerlach et al.	2007
		Seifert et al.	2008
High grade SAH		Ogilvy and carter et al.	2003
Extended cranial base access		Gerlach et al.	2007
		Seifert et al.	2008
Vasospasm		Ogilvy and carter et al.	2003
Posterior circulation		Gerlach et al.	2007
		Seifert et al.	2008
Poor medical condition		Soloman et al.	1994
		Yoshimoto and Meizoi et al.	1997

6. Conclusion

We have reviewed here the most common factors which have a vital role while selecting the patients with intracranial aneurysm to go for endovascular management or the microsurgical clipping. It is not always a wise decision to make one management better than other. One should try to give the best management to the patient with guidance of literature and personal skills. The responsible way to compare both would be a good randomized trial with comparable recruitment and find the outcome.

Disclosure

We declare that we don't have any conflict of interest.

Financement

Nil.

Declarations of interest

None.

References

[1] M.L. Platt, S.A. Huettel, Risky business: the neuro economics of decision making under uncertainty, Nat. Neurosci. 11 (4) (2008) 398–403.
[2] C.M. Korsgaard, Self-Constitution: Agency, Identity and Integrity, Oxford University Press, New York, 2009.
[3] C.S. Anderson, V. Feigin, D. Bennett, R.B. Lin, G. Hankey, K. Jamrozik, Active and passive smoking and the risk of subarachnoid hemorrhage: an international population-based case-control study, Stroke 35 (2004) 633–637.
[4] R. Bonita, Cigarette smoking, hypertension and the risk of subarachnoid hemorrhage: a population-based case-control study, Stroke 17 (1986) 831–835.
[5] V. Feigin, V. Parag, C.M. Lawes, A. Rodgers, I. Suh, M. Woodward, Smoking and elevated blood pressure are the most important risk factors for subarachnoid hemorrhage in the Asia-Pacific region: an overview of 26 cohorts involving 306,620 participants, Stroke 36 (2005) 1360–1365.
[6] V.L. Feigin, G.J. Rinkel, C.M. Lawes, A. Algra, D.A. Bennett, J. van Gijn, Risk factors for subarachnoid hemorrhage: an updated systematic review of epidemiological studies, Stroke 36 (2005) 2773–2780.
[7] B.A. Gross, P.M. Rosalind Lai, K.U. Frerichs, R. Du, Treatment modality and vasospasm after aneurysmal subarachnoid hemorrhage, World Neurosurg 8 (2014) 725–730.
[8] A.L. Ho, N. Lin, K.U. Frerichs, R. Du, Smoking and intracranial aneurysm morphology, Neurosurgery 77 (1) (2015) 59–66.
[9] B.M. Kissela, L. Sauerbeck, D. Woo, J. Khoury, J. Carrozzella, A. Pancioli, Subarachnoid hemorrhage: a preventable disease with a heritable component, Stroke 33 (2002) 1321–1326.
[10] S. Juvela, M. Hillbom, H. Numminen, P. Koskinen, Cigarette smoking and alcohol consumption as risk factors for aneurysmal subarachnoid hemorrhage, Stroke 24 (1993) 639–646.
[11] R. Bonita, Cigarette smoking, hypertension and the risk of subarachnoid hemorrhage: a population-based case-control study, Stroke 17 (1986) 831–835.
[12] W.T. Longstreth, L.M. Nelson, T.D. Koepsell, G. Belle, Cigarette smoking, alcohol use, and subarachnoid hemorrhage, Stroke 23 (1992) 1242–1249.
[13] Y.M. Ruigrok, E. Buskens, G.J. Rinkel, Attributable risk of common and rare determinants of subarachnoid hemorrhage, Stroke 32 (2001) 1173–1175.
[14] N.F. Kassell, J.C. Torner, The international cooperative study on the timing of aneurysm surgery. Part 2: surgical results, J. Neurosurg. 73 (1) (1990) 37–47.
[15] D. Roy, G. Milot, Endovascular treatment of unruptured aneurysms, Stroke 32 (9) (2001) 1998–2004.
[16] H.J. Cloft, D.F. Kallmes, Cerebral aneurysm perforations complicating therapy with Guglielmi detachable coils: a meta-analysis, Am. J. Neuroradiol. 23 (10) (2002) 1706–1709.
[17] J. Raymond, F. Guilbert, Long-term angiographic recurrences after selective endovascular treatment of aneurysms with detachable coils, Stroke 34 (6) (2003) 1398–1403.
[18] A. Molyneux, R. Kerr, International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized trial, Lancet 360 (9342) (2002) 1267–1274.
[19] A. Campi, N. Ramzi, Retreatment of ruptured cerebral aneurysms in patients randomized by coiling or clipping in the International Subarachnoid Aneurysm Trial (ISAT), Stroke 38 (5) (2007) 1538–1544.
[20] S.C. Johnston, C.F. Dowd, Predictors of rehemorrhage after treatment of ruptured intracranial aneurysms: the Cerebral Aneurysm Rerupture After Treatment (CARAT) study, Stroke 39 (1) (2008) 120–125.
[21] P. Mitchell, R. Kerr, Could late re-bleeding overturn the superiority of cranial aneurysm coil embolization over clip ligation seen in the International Subarachnoid Aneurysm Trial, J. Neurosurg. 108 (3) (2008) 437–442.
[22] J. Raymond, F. Guilbert, Clip versus coil, J. Neurosurg. 110 (1) (2009) 190–191.
[23] F.K. Hui, A.J. Schuette, Endovascular treatment of an aneurysm of a persistent primitive hypoglossal artery with complete resolution of brainstem compressive symptoms: case report, Neurosurgery 68 (3) (2011) E854–E857.
[24] J. Park, D.H. Kang, Superciliary keyhole surgery for unruptured posterior communicating artery aneurysms with oculomotor nerve palsy: maximizing symptomatic resolution and minimizing surgical invasiveness, J. Neurosurg. 115 (4) (2011) 700–706.
[25] P. Schuss, E. Guresir, Influence of surgical or endovascular treatment on visual symptoms caused by intracranial aneurysms: single-center series and systematic review, J. Neurosurg. 115 (4) (2011) 694–699.
[26] K. Houkin, S. Kuroda, Intraoperative premature rupture of the cerebral aneurysms. Analysis of the causes and management, Acta Neurochir. 141 (12) (1999) 1255–1263.
[27] M. Sluzewski, W.J. Van Rooij, Small aneurysm size is a risk factor for perforation during coiling, AJNR Am. J. Neuroradiol. 24 (10) (2003) 2122.
[28] T.N. Nguyen, J. Raymond, Association of endovascular therapy of very small ruptured aneurysms with higher rates of procedure-related rupture, J. Neurosurg. 108 (6) (2008) 1088–1092.
[29] A.J. Molyneux, R.S. Kerr, International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized comparison of effects on survival, dependency, seizures, re-bleeding, subgroups, and aneurysm occlusion, Lancet 366 (9488) (2005) 809–817.
[30] M.T. Lawton, R.F. Spetzler, Surgical management of giant intracranial aneurysms: experience with 171 patients, Clin. Neurosurg. 42 (1995) 245–266.
[31] Y. Murayama, Y.L. Nien, Guglielmi detachable coil embolization of cerebral aneurysms: 11 years' experience, J. Neurosurg. 98 (5) (2003) 959–966.
[32] J. Raymond, ISAT II Paper in Progress, (2011).
[33] Lawton MT. Basilar apex aneurysms: surgical results and perspectives from an initial experience. Neurosurgery. 50 (1): 1–8.
[34] J. Raymond, D. Roy, Endovascular treatment of acutely ruptured and unruptured aneurysms of the basilar bifurcation, J. Neurosurg. 86 (2) (1997) 211–219.
[35] T.N. Nguyen, J. Raymond, Endovascular treatment of pericallosal aneurysms, J. Neurosurg. 107 (5) (2007) 973–976.
[36] Y.I. Orz, K. Hongo, Risks of surgery for patients with unruptured intracranial aneurysms, Surg. Neurol. 53 (1) (2000) 21–27.
[37] L. Regli, A. Dehdashti, Endovascular coiling compared with surgical clipping for the treatment of unruptured middle cerebral artery aneurysms: an update, Acta Neurochir Suppl 82 (2002) 41–46.
[38] A.D. Bowry, M.A. Brookhart, Meta-analysis of the efficacy and safety of clopidogrel plus aspirin as compared to antiplatelet monotherapy for the prevention of vascular events, Am. J. Cardiol. 101 (7) (2008) 960–966.
[39] R. Sorensen, M.L. Hansen, Risk of bleeding in patients with acute myocardial infarction treated with different combinations of aspirin, clopidogrel, and vitamin K antagonists in Denmark: a retrospective analysis of nationwide registry data, Lancet 374 (9706) (2009) 1967–1974.
[40] C. Raftopoulos, P. Goffette, Surgical clipping may lead to better results than coil embolization: results from a series of 101 consecutive unruptured intracranial aneurysms, Neurosurgery 52 (6) (2003) 1280–1287.
[41] R. Gerlach, J. Beck, Treatment related morbidity of unruptured intracranial aneurysms: results of a prospective single centre series with an interdisciplinary approach over a 6-year-period (1999–2005), J. Neurol. Neurosurg. Psychiatry 78 (8) (2007) 864–871.
[42] V. Seifert, R. Gerlach, The interdisciplinary treatment of unruptured intracranial aneurysms, Dtsch. Arztebl. Int. 105 (25) (2008) 449–456.
[43] N. Aghakhani, G. Vaz, Surgical management of unruptured intracranial aneurysms that are inappropriate for endovascular treatment: experience based on two academic centers, Neurosurgery 62 (6) (2008) 1227–1234.

[44] H. Meng, V.M. Tutino, J. Xiang, A. Siddiqui, High WSS or low WSS? Complex interactions of hemodynamics with intracranial aneurysm initiation, growth, and rupture: toward a unifying hypothesis, AJNR Am. J. Neuroradiol. 35 (2014) 1254–1262.
[45] J.R. Cebral, F. Mut, J. Weir, C. Putman, Quantitative characterization of the hemodynamic environment in ruptured and unruptured brain aneurysms, AJNR Am. J. Neuroradiol. 32 (2011) 145–151.
[46] J. Xiang, S.K. Natarajan, M. Tremmel, D. Ma, J. Mocco, L.N. Hopkins, et al., Hemodynamic morphologic discriminants for intracranial aneurysm rupture, Stroke 42 (2011) 144–152.
[47] Y. Miura, F. Ishida, Y. Umeda, H. Tanemura, H. Suzuki, S. Matsushima, et al., Low wall shear stress is independently associated with the rupture status of middle cerebral artery aneurysms, Stroke 44 (2013) 519–521.
[48] M. Maruf, Y. Yasuhiro, T. Kawase, T. Riki, K. Miyatani, K. Yoko, Computational fluid dynamics in unruptured intracranial aneurysms, Romanian Neurosurgery 32 (2) (2018) 332–339.
[49] T. Aoki, K. Nozaki, Preemptive medicine for cerebral aneurysms, Neurol Med Chir. Neurol Med Chir. 56 (2016) 552–568.
[50] R.Y. Chung, B.S. Carter, A. Norbash, R. Budzik, C. Putnam, C.S. Ogilvy, Management outcomes for ruptured and unruptured aneurysms in the elderly, Neurosurgery 47 (2000) 827–833.
[51] J. Inamasu, T. Tanaka, A. Sadato, M. Hayakawa, K. Adachi, Outcomes of surgical versus endovascular repair of unruptured brain aneurysms in individuals aged ≥75 years, Geriatr Gerontol Int 14 (2014) 858–863.
[52] M. Ryttlefors, P. Enblad, R.S. Kerr, A.J. Molyneux, International subarachnoid aneurysm trial of neurosurgical clipping versus endovascular coiling: subgroup analysis of 278 elderly patients, Stroke 39 (2008) 2720–2726.
[53] M.J. Smith, M.R. Sanborn, D.J. Lewis, R.W. Faught, V. Vakhshori, S.C. Stein, Elderly patients with intracranial aneurysms have higher quality of life after coil embolization: a decision analysis, J Neurointerv Surg 7 (2015) 898–904.
[54] A. Steklacova, O. Bradac, F. Charvat, P. De Lacy, V. Benes, “Clip first” policy in management of intracranial MCA aneurysms: single-centre experience with a systematic review of literature, Acta Neurochir. 158 (2016) 533–546.