Factors influencing outcome following intraoperative rupture during surgical clipping of anterior communicating artery aneurysms.

Submitted for MCh Neurosurgery

By

Dr. Nilesh R. Agrawal

October 2006
Department of Neurosurgery

Sree Chitra Tirunal Institute
For
Medical Sciences & Technology
Trivandrum - 695011

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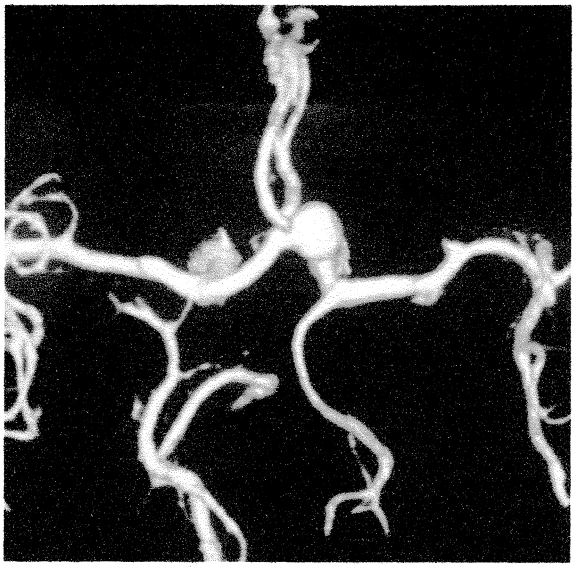

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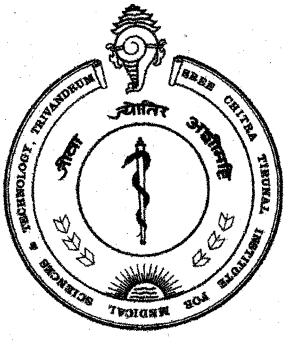

Submitted by	:	**Dr. Nilesh R. Agrawal**
Programme	:	**MCh Neurosurgery**
Month & Year of submission	:	**October 2006**

CERTIFICATE

This is to certify that the study

"Factors influencing outcome following intraoperative rupture during surgical clipping of anterior communicating artery aneurysms."

has been carried out by Dr. Nilesh R. Agrawal

in

Department Of Neurosurgery,

Sree Chitra Tirunal Institute

For

Medical Sciences & Technology

Prof. Dr. Suresh Nair
Head Incharge,
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Date:

Acknowledgement

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Trivandrum, Dr. Nilesh R. Agrawal

October, 2006

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Introduction

Advances in technology, instrumentation, and surgical technique have decreased the morbidity associated with the surgical treatment of intracranial aneurysms. Still, intraoperative rupture (IOR) of an aneurysm remains a well-recognized risk that can affect the patient's chance for a good recovery and significantly increase the risk of an adverse outcome .As with most intraoperative misadventures, intraoperative rupture is a complication that is better avoided than managed. Investigating and assessing the factors associated with IOR may help to diminish its frequency and thus advance patient care. Such an analysis may help to determine which factors should prompt the surgeon to consider alternative strategies for obliterating the aneurysm or alert the surgeon to maintain an even higher vigilance regarding the technical considerations that may prevent such an adverse occurrence.

Anterior communicating artery (AComA) aneurysms are considered to be more predisposed to intraoperative rupture [1,2] than other aneurysms by many authors. Although abundant literature is available on various aspects of intraoperative rupture of intracranial arterial aneurysms in general, there are very few articles specific to anterior communicating artery aneurysm rupture. Factors determining the risks of rupture are essentially the same in all aneurysms. However anterior communicating artery aneurysms present different challenges with respect to the variable types of circulation and projections.

Aims & Objectives

1. To determine the factors predisposing to intraoperative rupture during surgical clipping of anterior communicating artery aneurysms.
2. To determine the factors influencing outcome following intraoperative rupture during surgical clipping of anterior communicating artery aneurysms.

The following variables were analyzed to ascertain their influence on outcome

- Pre op grade
- History of repeated rebleeds
- Timing of surgery following the ictus
- Size of aneurysm
- Presence of vasospasm
- Presence of hydrocephalus
- Multiplicity
- Projection of aneurysm
- Type of circulation
- Time of intraoperative rupture
- Temporary clip application
- Duration of temporary clip application.

Material and Methods

Retrospective analysis of 378 cases of Anterior communicating artery aneurysms operated from Jan 1996 to December 2005 was done at Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), Trivandrum. Of these there were 102 patients who had intraoperative rupture. This study was confined to the 75 of these cases, whose diagnostic preoperative cerebral angiographic films were available for review. Those factors that might have predisposed to IOR or contributed to a favorable or unfavorable outcome were analyzed in detail.

All patients were approached through pterional approach and side was decided based on type of circulation. Clinical details like age, gender, World Federation of Neurological Surgeons (WFNS) grade and timing of surgery were evaluated from the records. Radiological parameters like size of aneurysm, vasospasm, multiplicity, projection of aneurysm, type of circulation were noted. Aneurysm size of 10 mm or less was taken as small, >10-24 mm as large and more than 25 mm as giant. All the diagnostic preoperative cerebral angiographic films were analyzed with the help of qualified radiologist. Operative details including timing of rupture, temporary clipping time was recorded from the operation records.

Fishers exact test and Pearson's analysis was used for statistical analysis. A p value of < 0.05 was considered as significant and p value of < 0.01 was considered to be highly significant. Outcome was assessed at discharge and at follow up in out patient clinic using the Glasgow outcome scale(GOS), in which patients whose score was 1-2 were classified as having good outcome and those with score of 3-5 were classified as having poor outcome.

In postoperative period they were monitored extensively in the ICU with triple H therapy use for the suspected vasospasm based on clinical/radiological / operative findings.

Study Limitations

This study is limited by the inherent drawbacks of a retrospective analysis. Although many of our patient data were entered concurrently into a computerized aneurysm database, we also relied on operative and radiographic reports as well as other documentation. We were limited by incomplete information in some patient records; it was not possible to consistently assess variables such as the length of temporary occlusion, presence of atherosclerosis. As previously mentioned, possible selection biases in the application of temporary occlusion cannot be assessed retrospectively. In addition, determination of the severity of IOR and short-term outcome in patients with IOR was based on subjective criteria.

Overall, we are comfortable with the reliability of the information that we were able to extract from the medical records, and we took care to note when specific data were insufficient. Only a large prospective study can overcome these weaknesses. However, even a prospective analysis of some of these issues would be hindered by their inherently subjective nature.

Review of literature

Anterior communicating artery aneurysms

Normal Anatomy

The basic configuration is two anterior cerebral arteries, each arising from one of the internal carotid arteries and passing under the inferior frontal lobe. At the midline, each arising from one of the internal carotid turns upwards to run in the interhemispheric fissure along the medial aspect of each hemisphere. The genu of the anterior cerebral arteries is joined by anterior communicating artery.

A1 Segment

The length of intracranial segment of internal carotid artery varies from 14 to 25 mm (average of 12.7mm) and that of the A1 segment varies from 7 to 8 mm. The diameter of the A1 segment varies from 0.9 to 4 mm (average of 2.6mm). [3] Although a disparity between the diameters of the two A1 segments is common, this disparity is greater than 1 mm in only 6 to 12 percent of the general population.[4,5,6] Some disparity between the diameters of the two A1 segments has been noted in up to 90 percent of the patients harboring anterior communicating artery aneurysms.[7] In 50 percent of the cases presenting with ruptured anterior communicating artery aneurysm, the disparity is greater than 1 mm. [6, 8] The A1 - anterior communicating artery junction lies over the optic chiasm in 70 percent of the cases and over the optic nerve in 30

percent of the cases. Prior to crossing the optic chiasm, the A1 segment passes through a thick arachnoid membrane marking the lateral wall of the lamina terminalis cistern.

Anterior communicating artery

Embryology

In a 40-day-old embryo, an arterial plexus that gives rise to the median artery of the corpus callosum at the age of 45 days connects the two anterior cerebral arteries. Afterward this artery regresses or disappears, [9] at the same time the involution of the arterial plexus leads to the formation of the anterior communicating artery. Dunker [10] classified three different anatomical patterns of the anterior communicating artery. Fetal type, in which the anterior communicating artery is equivalent in diameter to the anterior cerebral artery segment and a large median callosal artery, is present. Transitional type, corresponding to a smaller anterior communicating artery than the anterior cerebral artery segment with a small median callosal artery. Adult type, in which the anterior communicating artery's diameter is less than one-third that of the anterior cerebral artery segment with the absence of the medial callosal artery or only persistence of a small protrusion.

The anterior communicating artery is 2 to 3.4 mm in diameter (average 1.5 mm). The diameter is proportional to the disparity in the diameters of the two A1 segments. A classic single anterior communicating artery joins in only 40 to 60 percent of the anterior cerebral arteries. The artery length varies from 0.8 to 4. 6 mm. The anterior communicating artery generally lies on the optic chiasma at the level of the lamina terminalis.

Branches

The anterior communicating artery gives origin to 1 to 13 perforating vessels. [11,12,13] Although these vessels may originate from any point around the circumference of the anterior communicating artery, 70% pass at an angle of 90 to 120 degrees posterior to the distal anterior cerebral arteries (A2 segments) when measured in the sagital plane.[14]

No branches were evident from the anterior aspect of the anterior communicating artery. These perforating vessels are present in all specimens of cadaver dissections except in those with the median artery of the corpus callosum and the azygous ACA.

Anterior communicating artery aneurysms

Most recent neurosurgical series report anterior communicating artery complex as the most common site for intracranial aneurysms. [15, 16,17,18,19,20,21,22]

Table: Distribution of intracranial aneurysms[15]

Aneurysm site	Incidence
ICA	29.8%
MCA	22.3%
ACA	39.0%
VB	7.6%
Others	2.0%

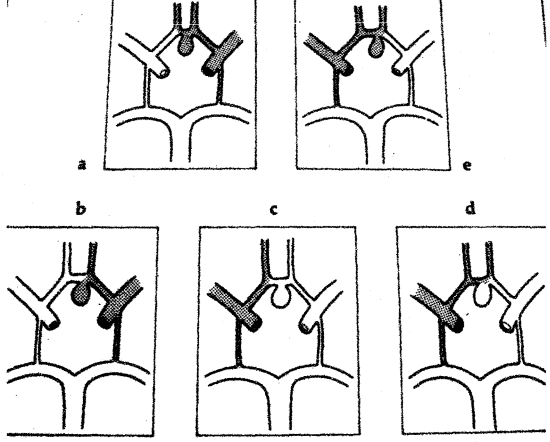
Approximately 55 percent of the anterior communicating artery aneurysms that receive clinical attention are 6 to 10mm diameter, 20 percent are less than 6 mm and 25 percent are 11 to 25 mm in diameter. Giant anterior communicating artery aneurysms are rare.

Type of circulation

Norlen and Barnum [23] drew attention to different patterns of circulation through the anterior part of circle of Willis in patients with anterior communicating artery aneurysms stressing their importance for various surgical procedures. Sengupta [24] noted four types of circulation, and aneurysms were classified accordingly.

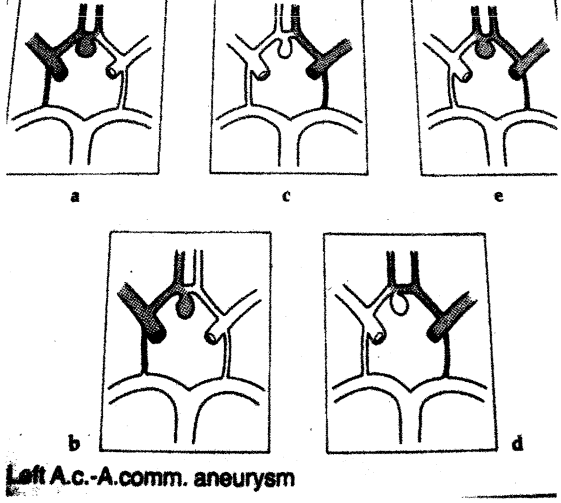
Type 1: (Ipsilateral) In this type, the aneurysm and the distal anterior cerebral artery filled from one proximal anterior cerebral artery.

1. Right anterior cerebral –anterior communicating artery aneurysms. The pattern of circulation in these aneurysms may be as follows-
    a) Right carotid injection fills the aneurysm and both the distal anterior cerebral arteries.
    b) Right carotid injection fills the aneurysm and right distal anterior cerebral artery.
    c) Left carotid injection fills the left distal anterior cerebral artery only.
    d) Left carotid injection with right carotid compression fills both distal anterior cerebral arteries but not the aneurysm.
    e) As in d), but the aneurysm fills.

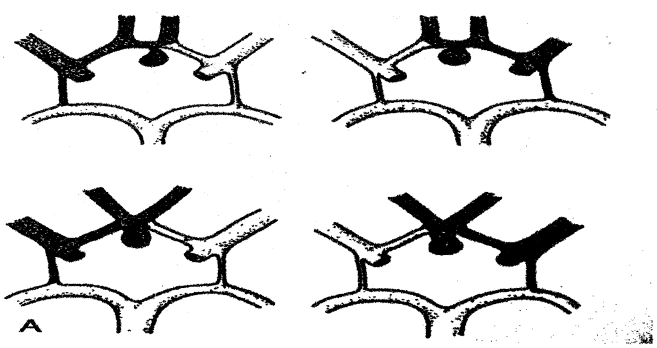


Right A.c.-A.comm. aneurysm

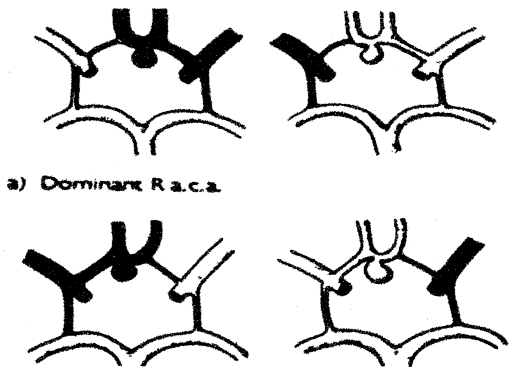
2. Left anterior cerebral –anterior communicating artery aneurysms. In these aneurysms the following patterns of circulation are possible-
    a) Left carotid injection fills the aneurysm and both the distal anterior cerebral arteries.
    b) Left carotid injection fills the aneurysm and the left distal anterior cerebral artery.
    c) Right carotid injection fills the right distal anterior cerebral artery only.
    d) Right carotid injection with left carotid compression fills both distal anterior cerebral arteries but not the aneurysm.
    e) As in d, but the aneurysm fills.



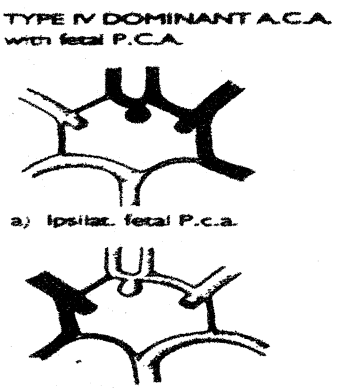
Type 2: (Bilateral) - In this type, the aneurysm and both anterior cerebral arteries fill from both carotid injections. This pattern of circulation is often associated with rudimentary anterior communicating arteries. Infact, both anterior cerebral arteries may be fused to each other .On the other hand, the anterior communicating artery may be seen as a prominent structure on the angiograms .The significance of this analysis is that in this type of circulation the region of the anterior communicating artery receives good collateral supply, and the effect of vasospasm is minimal. In cases of rudimentary anterior communicating arteries, however, application of a clip may lead to kinking of both anterior cerebral arteries, leading to severe ischemic problems.



Type 3: (Dominant anterior cerebral artery) –In this type, the aneurysm arises from the axilla of the two distal anterior cerebral arteries, both of which are divisions of the dominant anterior cerebral artery, and the contralateral artery is hypoplastic.



Type 4: (Dominant anterior cerebral artery with foetal posterior cerebral artery)- In this type, the circulatory patterns are like those in type 3, but there are other associated anomalies in the circle.



Projections-

Anterior communicating artery aneurysms can project at any angle in three-dimensional space. Classification of these lesions is based on their orientation in the true anatomical space using the optic nerves as a rough anteroposterior axis.

Gary Vanderark et al [25]categorized Anterior communicating artery aneurysms by the direction in which it is projected (measured as straight line from base to fundus) into:

1. Superior	2. Anterior	3. Inferior
4. Posterior	5. Anterosuperior	6. Posteroinferior
7. Anteroinferior	8. Posterosuperior.	

Yasargil [26] classified AcomA projections under five groups:

1. Anterior	2. Superior	3. Inferior
4. Posterior	5. Complex	

Nathal E et al [27], further modified it and classified projection of aneurysms into

- Type 1-Aneurysms located anterior to the bilateral A2 portions of the ACA
- Type 2-Aneurysms located between the bilateral A2 portions of the ACA
- Type 3-Aneurysms located posterior to the bilateral A2 portions of the ACA

Vincentelli et al [14] in their study of 60 fixed human brains, indicated that all perforating branches followed a posterior direction and formed an angle with the pericallosal arteries that ranged between 30 and 180. Perlumtter and Rhoton [13] showed that 90% of perforating arteries arising from the AComA were branched on the superior and posterior facies. Yasargil [26] - considered this to be a predominant anatomical factor. These authors observed a decrease in

positive outcomes and an increase in the mortality rate among patients with superiorly, posteriorly, and inferiorly projecting aneurysms. In these latter projections, the dissection of arteries comprising the AComA complex, recurrent arteries of Heubner, frontopolar and frontoorbital arteries, and hypothalamic arteries from the neck of the aneurysm were all considered a source of complication. Conversely, for aneurysms with anterior projection, these arteries are often avoided. According to Yasargil [26] different projections are-

Superior Projection Aneurysms:

Frequently associated with a dominant ipsilateral A1 vessel, these lesions usually do not conceal the opposite optic nerve. This project into the interhemispheric fissure and the contra lateral A1 / A2 junction is concealed by the aneurysmal fundus. This is the most common direction of the projection of the aneurysmal fundus and may be partially embedded in contralateral gyrus rectus. These are generally more easily handled than aneurysms projecting in other positions. Gyrus rectus resection can be helpful to mobilize the fundus. If the frontoorbital and frontopolar arteries are attached to the wall of the aneurysm it can be troublesome.

Anterior Projection Aneurysms:

These types fill the space between the two optic nerves, may remain within area of lamina terminalis and may be attached to dura of anterior wall of sella turcica over tuberculam sella. Account for 20 to 25 percent of the aneurysms. They may become entangle to chiasmatic cistern. Larger aneurysm may displace aneurysm out of interhemispheric fissure.

Posterior Projection Aneurysms:

These lesions project both above and below the plane formed by the two A2 segments and usually conceal the contra lateral A2 take off. Almost always involve early incision into ipsilateral gyrus rectus to visualize the anatomical structures. The chiasm is uninvolved. Fenestrated clips may be helpful for the definitive clipping of the posterior projection anterior communicating artery aneurysms.

Inferior Projection Aneurysms:

These projections are considered to be the most difficult to handle. The hypothalamic arteries are usually attached to anterior wall of these aneurysms. Fundus may directly project into lamina terminalis cistern. Due to intimate association with the perforating vessels and the difficult angle for clipping, these lesions are treacherous and almost always require an extensive gyrus rectus resection to allow complete visualization of the aneurysmal fundus.

Complex projection:

This aneurysm may project in any or all directions and are typically quite large with lobulations.

By noticing the orientation of the fundus the surgeon will be alert to the particular problems, which may occur at the time of surgery. However one thing worth considering and important is that there is a significant difference between the description of the aneurysm projection given by the radiologist and that actually found by a surgeon at the time of the surgery. Inferior or anterior projection aneurysms may become tethered to the optic chiasm or tuberculam sella. A bulbous inferior or anterior directing lesion can obscure the surgeon's view of the opposite A1 segment. Retraction of the medial frontal lobe could precipitate a premature rupture of the aneurysm. A superior pointing aneurysm can become adherent to the A2, frontoorbital or frontopolar arteries. Posterior pointing fundus can often become adherent to the perforating vessels. The surgeon must be aware of the multilobulated aneurysm. Particularly troublesome are the aneurysms with a superior and posterior projection. The surgeon may clip the superior portion of the aneurysm between the two A2 segments thereby obscuring the still patent posterior portion of the aneurysm.

Operative approaches- Surgery

Surgical clipping is the standard modality of treatment in the ruptured intracranial aneurysms including Acom artery aneurysms. The earliest series reported dismal results for surgery of ruptured Acom aneurysms[28]. However, by the 1970s certain surgeons made significant progress [29,30,31,32]. Emergent surgery is performed for aneurismal rupture, resulting in large frontal intracerebral hemorrhages. The vast majority of patients with SAH from Acom artery aneurysms undergo early craniotomy and clipping following ICU monitoring and triple –

H therapy. Several factors dictate the side of approach and the type of approach in the management of ruptured Acom artery aneurysms. The two standard types of approaches used are as follows-

Bifrontal Craniotomy

Tonnis[31] first described the bifrontal approach to Acom artery aneurysms in 1936. His high craniotomy technique involved resection of the genu of the corpus callosum to reach the Acom artery complex. Pool subsequently reported a low bifrontal approach, with closure of the violated frontal sinuses with a vascularised pericranial flap[31]. French[30] advocated a right unilateral frontal craniotomy with a wedge resection of the mesial frontal lobe. Suzuki[33] has recently reported his experience with this approach. He employed a very low-lying craniotomy and meticulously dissected the olfactory tracts from the undersurface of the frontal lobes, thereby preserving olfaction. Using the operating microscope, an interhemispheric dissection can be performed through a small bony opening. [30,34]

Pterional approach

Modifications such as Yasargil's pterional[26] and Chehrazi's [35] transsylvian approach have been proposed. A variant of one of these approaches is employed by most of the surgeons.

Initial approach – Several factors dictate the approach of the Acom artery aneurysms. These lesions are generally approached from the side of the dominant A1 vessel filling the

aneurysm. This is usually 180° away from the flow directed axis and the spatial projection of the fundus.

Summary of operative technique- pterional approach (Sequence varies depending on fundus projection)

- Frontotemporosphenoidal craniotomy
- Opening the sylvian, carotid and interpeduncular cisterns.
- Opening the lamina terminalis cistern and control of ipsilateral A1 segment.
- Dissection of the lamina terminalis cistern over the contra lateral A1 segment to the opposite ICA.
- Ipsilateral partial gyrus rectus resection.
- Identification of the A2 segments and the branches.
- Identification of the recurrent arteries of Heubner.
- Dissection of the frontoorbital and frontopolar arteries from the aneurysm.
- Identification of the hypothalamic arteries.
- Bipolar coagulation of the bulging parts of the aneurysm or of the neck of aneurysm.
- Clip application to the properly prepared neck of the aneurysm.
- Fundus resection.
- Check for adequacy of clip placement.
- Homeostasis and closure.

Intraoperative rupture & anterior communicating artery aneurysms

Definition

The exact definition of intraoperative rupture is controversial and this intuitive fact has led to variation in the reporting of intraoperative rupture. Chandler et al [36] defined intraoperative rupture (IOR) as "bleeding that interrupts and alters the sequence of the microsurgical procedure. Not included are the trivial leaks that are easily handled by most neurosurgeons. Giannotta et al [37] also excluded "minor hemorrhages during clip application which were controlled by simply closing the clip blades." Sandalcioglu, [38] however defined intraoperative aneurysm rupture (IAR) as aneurysmal rupture during different steps of the surgical procedure including rupture during the dissection of the aneurysm and rupture during clip application or clip transposition. Ruptures during dural incision, the use of brain retractors or removal of intracerebral hematoma was not included as IOR. A bleeding was considered significant if the surgeon was forced to change his operative procedure. Conversely, Le Roux et al [39,40], Rinne et al [41] and Schramm [1] included small bleeds as well and all forms of bleeding including those, which occurred during closure of the clip blades and persistent bleeding after closure of the clip blades. Leipzig T J [2] have provided a more inclusive definition and in their extensive review of 1694 cases of intraoperative rupture included all cases of ruptures from the time of induction of anesthesia until completion of the procedure.

Incidence

As Batjer [42,43] pointed out, there are surprisingly few papers on the incidence of intra-operative rupture of aneurysms. In particular, as far as the macroscopic technique is concerned, there are only a small number of papers reliable enough for citation. According to a cooperative study (multicenter randomized study between 1963 and 1970), the incidence of intra-operative rupture of an aneurysm without the microsurgical technique was a surprisingly low 18% [44]. This extremely low incidence more than 30 years ago is difficult to straightforwardly evaluate. On the other hand, Pertuiset [45] reported that intra-operative rupture of aneurysms in surgery without the microscope occurred in 36% of cases in 1979, which seems to be quite reasonable, moreover before the routine use of the operative microscope, some studies reported IOR in more than half of the patients [46,47]. However, it is plausible that the definition of intra-operative rupture was quite narrow, as was the definition of premature rupture.

In an early microsurgical series of 500 operated aneurysms Jomin et al [47] reported that approximately 20% of the aneurysms ruptured during operation. Batjer [42, 43] recorded an incidence of 45%, whereas Giannotta et al [37] reported an incidence of 14.3%. This difference seems to be due to the definition of intra-operative rupture. Batjer's study included haemorrhage during clip application, which accounted for 45% of the ruptures, whereas Giannotta excluded minor hemorrhages during clip application. When we summarize these data, the incidence of all intra-operative ruptures including minor haemorrhage, reaches approximately 20%. The incidence of serious hemorrhage seems to be between 10% to15% (14.3% in Giannotta's paper and 10.5% calculated from Batjer's paper excluding the rupture during clip application). [37,43] Very serious intra-operative rupture (premature rupture) occurs in approximately 5% of cases. More recently, IOR rates have ranged between 15 and fifty percent.[1, 37, 39, 43, 44, 48, 49] Although

several series report much lower incidence. [50,51] The main reason for this large variation is probably due to the different definitions of the term "intraoperative aneurysm rupture".

Predisposing factors

A. Mechanisms and causes of rupture

Several factors have been associated with IOR. Elevated preoperative systolic blood pressure, Fischer grade, brain swelling and intracerebral hemorrhage seem to correlate with an increased incidence of IOR but have not been conclusively proven.

Very early premature ruptures like the ones, which happen during induction of anesthesia or dural opening, seem to be unavoidable since they had nothing to do with surgical techniques. Fortunately these types of premature ruptures are extremely uncommon and very few authors have reported them. Premature rupture of the aneurysm before the opening of dura mater, have been reported in some papers. [42, 47] These are literally catastrophic ruptures and their outcome is usually disappointing. As mentioned, some of ruptures could have been avoided if much more deliberate technique and the right strategy had been used. However, many of them are still unavoidable even if they are retrospectively reviewed. Houkins [50] mentions 5 cases (21% of premature ruptures and 1.3% of all cases) of very early premature rupture prior to the substantial dissection of the aneurysm, which was induced by simple opening of the dura mater and arachnoid membrane and minimum haematoma removal. As analyzed in his study, the outcome was poor in these cases. In Leipzig T J series[2], IOR occurred in the predissection phase in 5.3%

of aneurysms. This corresponds to the rate of 0.62 to 8.3% reported in other studies [37, 38, 52, 53, 54] and reemphasizes the necessity of careful technique for induction of anesthesia.

However, the prediction of such early premature ruptures is likely to be possible in some cases. Namely, very poor grade subarachnoid haemorrhage with massive intracerebral haematoma and /or subdural haematoma with signs of re-rupture during the preoperative period, for example during angiography, seems to indicate a high risk of a very early premature rupture. In other words, it is reasonable that a ruptured aneurysm with these radiological signs easily ruptures when it is decompressed by some surgical procedure such as opening the dura or removing the haematomas. Although few neurosurgeons have advocated the need for predicting premature rupture and prophylactically using pharmacologically induced hypotension and or hypothermia, their use is controversial.

At present, there is no effective management for such premature ruptures once they occur except for the resection of the part of the brain or haematomas under deep hypotension.

Other causes of premature rupture are related to the procedures of dissection of the aneurysm neck and parent arteries. Bleeding from a ruptured aneurysm is ``temporarily" halted by the thrombus over the ruptured point adhering to the surface of the brain or other tissue and by the haematoma. In other words, any ruptured aneurysm has the possibility of re-rupture during surgery by procedures pointed out by Yasargil and Smith. [48] The stability of this temporary haemostasis is never accurately estimated from pre-operative information. The procedure of aneurysm dissection is in some sense a technique of compromise between a dissection of the normal structure and preservation of this temporary haemostasis leaving it untouched. Therefore, the dissection can jeopardize this temporary haemostasis and thus there is the possibility of premature rupture at any time. Houkin[50] categorized the dissection technique

into the left-hand ``blunt" procedure and right hand ``sharp" procedure. Batjer [42] reported that blunt dissection led to more rupture than sharp dissection a fact contradicted by Houkin[50] for want of sufficient evidence. As Ausman and Diaz[55] pointed out in their comment about Batjer's report, the technical aspects of aneurysm surgery are very critical in the analysis of these issues although they are very difficult to scientifically analyze. In addition, the factor of the surgeon's experience and capability presumably has a significant impact on the incidence of rupture and its outcome.

Rupture during dissection of the aneurysm can occur because of "tugging" on tissues adherent to the aneurysm or by direct tearing or puncture of the aneurysm by the dissecting instrument. Most of intraoperative ruptures during dissection occurred while working in close proximity to the aneurysm during definitive micro dissection, usually while trying to define the base or dissecting along the wall of the aneurysm. Bleeding occasionally is caused by application of the clip itself. Such a rupture may result from increased turgor in the dome of the aneurysm secondary to pressure transmitted from the neck with closure of the clip, detachment of an adherent dome as closure of the clip slightly moves the aneurysm, tearing of the neck by misapplication of the clip (possibly because of incomplete dissection around the aneurysm), or shearing of an aneurysm neck from the vessel wall. Also, some aneurysms are so inherently fragile that the wall of the aneurysm may not be strong enough to accept a clip.

B. Location

Although some believe that the incidence of IOR varies depending on the location of the aneurysm, many do not uniformly recognize location as a risk factor. Yasargil [26] was the first to

record a rupture rate of 25% in a series of operated anterior communicating artery patients. Several authors [1,37,38,56] observed higher rupture rates for aneurysms of the anterior circulation especially the anterior communicating artery aneurysm. In Van Linderts[51] study apart from the anterior communicating artery, aneurysm of the middle part of basilar artery and the pericallosal artery were associated with higher rates of IOR. Bertalanaffy et al [57] too recorded a high incidence of intraoperative rupture among anterior communicating artery aneurysms. However in their study the posterior communicating artery aneurysm, ophthalmic segment aneurysms and posterior inferior cerebellar artery aneurysms too showed elevated rates of IOR contrary to what was observed by Van Lindert.[51] Kopitnik [58] too observed a higher rupture rate for posterior communicating artery aneurysms and in his opinion the higher incidence for IOR is caused by specific anatomical constellations with a relatively immobile ICA, so that retraction of the temporal lobe can lead to rupture due to adhesions between the temporal lobe and the aneurysm dome. In Giannotta's [37] series basilar artery aneurysms showed increased IOR rates as well which was associated with poor outcome in majority of the cases unlike anterior communicating artery aneurysms rupture, which had a relatively good prognosis. Ljunggren [59] unlike other authors found that Middle cerebral artery aneurysms are more prone to leak or rupture during surgery.

C. Patient grade

Le Roux et al [39,40] and Schramm [1] reported no significant difference in the rate of IOR between good-grade (Grade I–III) and poor-grade (Grade IV–V) patients. Leipzig [2] has made a similar observation in his extensive analysis of 1694 patients with IOR.

D. Multiple rebleeds

Ruptured aneurysms had a significantly higher incidence of IOR compared with unruptured or remotely ruptured aneurysms and it is safe to assume based on available data that the risk of IOR for the surgical treatment of unruptured aneurysms is negligible. Aneurysms that have ruptured multiple times before surgery require special attention. The IOR rate for aneurysms with confirmed multiple SAH was more than three times that of the overall IOR rate in Leipzig's[2] series and one-quarter of all major IORs occurred in aneurysms with multiple SAH (suspected or confirmed). These composed 3.5% of Leipzig's series, compared with 29% of patients in the series reported by Sundt.[54]. Van Lindert[51] made a similar observation where unruptured aneurysms were found to have considerably lower rates than ruptured aneurysms (only 1.1% in their series).

E. Ruptured vs. unruptured aneurysms

It has been uniformly accepted by most authors that patients with unruptured aneurysms are less likely to experience an IOR, especially if temporary occlusion is used. Leipzig TJ [2] observed that in patients who experienced multiple SAH, the frequency and severity of IOR seems to be greater. The IOR rate for aneurysms with multiple SAH was more than three times greater than the average rate of IOR for all aneurysms. Early recognition and treatment of SAH may be one of the most important ways to reduce the risk of rebleeding as well as the risk of IOR.

F. Timing of Surgery in Relation to SAH

Since the 1980s, there has been greater emphasis on early surgical intervention to minimize the risk of rebleeding.[58] Disagreement exists regarding the influence of the timing of surgery on IOR. Studies by Le Roux et al [39,40] and Sundt et al[54] found that IOR was unrelated to the timing of surgery after SAH. Similarly the incidence of IOR in patient's subjected to early versus late operation has been reported to be the same for both groups by Kassell et al [53]. In previous studies, early surgery has been reported to be associated with a higher incidence for IOR [1,56,59].Schramm [1] found an increased IOR rate with early surgery (within 72 hrs after bleeding) with a fourfold higher IOR rate. In their study Schramm [1] concluded that the higher incidence of IOR in early surgery is due to a higher fragility of the clot occluding the rupture site and/or the aneurysmal sac. Lindert[51] found an increased incidence of IOR when surgery was performed in the first 48 hrs after bleeding; although significance was not reached. There is a clear aneurysmal vulnerability in patients admitted to early surgery. Sandalcioglu [38], in contrast, observed no correlation between the occurrence of IOR and the timing of surgery. He however observed that whereas the time of surgery showed no influence on the risk of IOR, early surgery seems to be weakly associated with an increased risk of unfavorable outcome as an independent factor. Similarly, in Leipzig's J [2] study, the average IOR rate for surgery performed 0 to 3 days after SAH was not remarkably different from the average IOR rate for surgery performed more than 3 days after SAH. However in their study surgery performed during the first 2 weeks after SAH compared with surgery performed later than 2 weeks, there seemed to be a reduction in the IOR rate after the second week. The IOR rate dropped from 11.2% during the first 2 weeks after

SAH to only 5.4% thereafter. However, when taking sample size into consideration (881 aneurysms operated on within the first 2 week versus 74 after the first 2 week) as well as the 15 aneurysms for which the exact number of days between SAH and surgery could not be determined, it is difficult to come to any definite conclusions. Overall, it seems that the timing of surgery in the first two weeks after SAH has little effect on the probability of an IOR. However, delayed surgery may decrease the risk of IOR.

G. Approach

Lindert [51] in his extensive review on intraoperative ruptures made this observation that the avoidance of brain retraction in the neighborhood of the aneurysm by choosing a contralateral approach may contribute to a lesser incidence of aneurysm rupture. In his study none of the 28 contralateral aneurysms ruptured. However any other author has not made such an observation and at present it appears too premature to comment on this.

H. Size and rupture

Although Sluzewski et al [60] documented that smaller aneurysms tended to have a higher rate of perforation, most authors agree that the size of the aneurysm does not seem to influence IOR rate. In Lindert [51] series none of the giant aneurysm ruptured during surgery. This has been confirmed in other studies [61] as well with the exception of Sundt [54] who found an increased rate of IOR in giant aneurysms.

I. Surgeons role

Adequate studies have not been done on the influence of the surgeons experience on the treatment of aneurysm and IOR as a scientific study on this aspect might prove to be unethical on many grounds. The only available study is the one by Lindert [51]. In this retrospective analysis he found that IOR was three times higher for surgeons who perform occasional aneurysm surgery compared to single surgeon who preformed more than 10 cases a year. Their study shows that surgical experience and the annual caseload inversely correlated with the IOR rate.

Severity of IOR

The severity of the IOR correlates with the ultimate impact on the patient. A large, uncontrollable IOR is more likely to injure a patient than is a small, brief leak that ceases with closure of the clip blades. Leipzig [2] in his extensive analysis of 1694 cases of intraoperative aneurysm rupture has attempted to classify the severity of each IOR. He classified the severity of IOR into three groups: minor bleed, moderate bleed, and major bleed. Minor bleeds from the aneurysm were small and easily controlled by a 3-French micro sucker or closure of the clip. Often, these were anticipated and did not interrupt or affect the surgical procedure. Moderate bleeding usually required temporary occlusion of the proximal arterial segment or tamponade of the aneurysm to stop the bleeding. Major IOR resulted in significant hemorrhage that was

difficult to control. The operating surgeon often described this as "profuse" or "brisk," bleeding that required larger-bore suction and possibly trapping of the aneurysm. Moderate and major bleeds are regarded as significant IOR. Leipzig[2] concluded that the more severe the IOR, the more likely it is that the patient will have a poor outcome.

Timing of IOR in Surgery

Yasargil [26, 49] was the first to point out that rupture occurred most usually during a) retraction of the brain b) dissection of the parent vessels of the aneurysm c) direct mobilization of the aneurysm .The time of IOR was further divided into five main time periods by Leipzig T J [2]: predissection, initial micro dissection, definitive micro dissection, clipping, and post clipping. Predissection IOR is defined as any IOR that occurred between induction of anesthesia and opening of the dura mater. IOR during initial micro dissection is defined as aneurysmal rupture that occurred while the parent vessels or branches were being defined. IOR during definitive micro dissection is defined as rupture occurring during exploration of the base or wall of the aneurysm or during an attempt to detach a branch vessel away from the aneurysm. IOR during clipping is defined as aneurysm rupture when the clip was being applied to it or if it occurred when the clip was manipulated. Any change of the clip after its initial application was considered a "clip manipulation". If bleeding occurred after the initial clip was reopened, moved, or reapplied, the IOR was defined as occurring during a clip manipulation. Post clipping IOR is defined as any IOR that occurred after placement of a permanent aneurysm clip (such as IOR caused by intentional puncture of an aneurysm that was incompletely clipped or placement of an additional permanent clip on the aneurysm).

Several studies have also investigated the time of occurrence of IOR in surgery. [36,37,42,43,50,54,61,62] Similar to the findings of Saito et al [62] and Batjer and Samson [42, 43], the vast majority (85.8%) of IOR s occurred during surgical manipulation around the aneurysm. This was nearly evenly divided between dissection around the aneurysm and clip application or adjustment.

In Leipzig T J [2] series, IOR occurred in the predissection phase in 5.3% of aneurysms. This corresponds to the rate of 0.62 to 8.3% reported in other studies [36, 37,52, 53, 54] and reemphasis the necessity of careful technique for induction of anesthesia. In Leipzig T J [2] series, IOR occurred during manipulation or reapplication of the clip on one or more occasions. There is no relationship between the number of clip applications and the number of IOR (P = 0.8399), and readjusting a clip to achieve optimal occlusion seems to be a relatively safe maneuver. Conceivably, some of the single clip applications may have been suboptimal, with readjustment of the clip-deferred secondary to concerns over the perceived fragility of the aneurysm.

Management of IOR

Intra-operative rupture of aneurysms is a disaster for patients since the outcome of patients who suffer intra-operative rupture can be poor compared to that of patients without intra-operative rupture. At the same time, intra-operative rupture of the aneurysm is a catastrophic event for neurosurgeons since it imperils a deliberate systematic surgical procedure based on microsurgical techniques. If an IOR occurred during aneurysm surgery the management of this IOR is the most important factor in the patient's outcome and must be tailored to the individual case. Only a few premature ruptures can be avoided by proper strategy and technique, even with

the benefit of microsurgical techniques. Many masters of neurosurgery have reported their management techniques for intra-operative rupture of aneurysms.

General maneuvers to control unexpected aneurysm rupture include focal tamponade, the double suction technique, the use of temporary clips on the parent arteries and induced hypotension. There are numerous studies reporting the experience and results using one of these methods or a combination. [36, 37, 42, 43]

Primary haemostasis or control of the bleeding was obtained by the conventional techniques such as suction and tamponade even in the case of premature rupture. It is quite important to be conservative in this panic and avoid additional injury to the brain and vessels by risky manipulations such as more retraction or application of a temporary clip without gaining control of the bleeding. The suction technique first mentioned by Poppen is the most frequently used and this technique has been introduced by many neurosurgeons such as French [63, 64] and Yasargil [48]. As Greenberg [65] concluded about this technique, suction of the ruptured aneurysm requires critical accuracy of maintaining the aneurysm sac within the sucker. He added the comment that the use of assistants to hold the sucker in the microsurgical field is occasionally awkward and bears the risk of inducing additional injury. This comment seems to be quite reasonable and to be agreed by many neurosurgeons with wide experience in aneurysm surgery. In order to overcome this problem, he mentioned his original self-sustaining holder for the sucker. Houkin [50] introduced the technique of double suction where the role of the assistant sucker is to clean up the overflowed blood in the microsurgical field, and the assistant can use two suckers in some cases. On the other hand, the role of the main surgeon's sucker is to concentrate on finding the point of rupture and then controlling it. Therefore the accuracy of handling the sucker is critical for the main surgeon but the assistant sucker can be moved more

freely. Once the rupture point is controlled by single suction without any additional injury, a simple cotton tamponade is still useful to obtain temporary haemostasis even in premature ruptures. On the other hand, in cases of very premature rupture immediately after opening the dura and arachnoid and removal of the haematoma, this traditional technique is generally useless. There is no good technique for managing such premature ruptures and the outcome is extremely poor. Accurate and swift decision making to sacrify some part of the brain and obtain the working space to apply a temporary clip can minimize the damage of this disaster.

In 1986, Ausman and Diaz [55] commented that the use of temporary occlusion in the surgical treatment of intracranial aneurysms significantly reduced the incidence of IOR. Several subsequent studies also reported the use of temporary occlusion to decrease IOR. In a retrospective analysis Gianotta[37] compared his clinical results of temporary clipping versus focal tamponade and revealed that additional use of hypotension to control IOR decreases favorable outcome significantly from 87% down to 38%. In accordance to Gianotta[37] several authors reported the use of temporary clips to be more effective and safer than hypo tension, [66, 67] although this may result in ischemic complications due to prolonged occlusion intervals. In particular, the territory of the perforating arteries is less tolerant to reduced perfusion. Thus, ischemic infarcts in functionally important structures can result in poor surgical outcome. Schramm[1] observed that the use of hypotension might be useful during dissection of the aneurysm, but must be restored in case of temporary vessel occlusion and that in case of temporary vessel occlusion the use of intraoperative somatosensory evoked potential (SSEP) is a helpful technical instrument.

In Linderts[51] series local control of IOR with aspirator or cottonoids (achieved in 33% of cases) was associated with good recovery whereas temporary clipping led to new neurological

deficits in 25% of cases. Duration of temporary clipping was of decisive importance whether neurological deficits occurred or not. Giannotta et al[37] however found no difference between local compression and temporary clipping in regard to outcome. Permissible artery occlusion times may differ but temporary clipping is generally regarded as safe for 10 – 20 minutes with cerebroprotective measures and in individual cases even for a longer period [68, 69]. In Linderts[51] study patients with permanent deficits attributable to temporary clipping had a mean occlusion time of 24 minutes whereas patients without deficits had a mean occlusion time of 5.5 minutes. Leipzig[2] observed that that aneurysms treated without temporary occlusion had more than twice the rate of IOR compared with aneurysms treated with temporary occlusion. Similarly ruptured aneurysms were temporarily occluded more often than unruptured lesions. There were no IORs in surgery for unruptured aneurysms treated with temporary occlusion in Leipzig's series. [2]

Recognition that premature rupture will occur under some rare conditions and is just a matter of "bad luck" for neurosurgeons using microsurgical techniques seems to be warranted. Very accurate and swift decision-making is required in the panic of the premature rupture of the aneurysm. Even more importantly, the neurosurgeon should keep this worst-case scenario in mind and simulate the crisis management before and during aneurysm surgery.

Whether the occurrence of IOR has an influence on outcome is still controversial. Several authors have addressed outcome in patients with IOR [1, 41, 50, 52] compared with those without IOR. There is general agreement that appropriate maneuvers to control IOR together with the surgeon's experience, now days affect a similar outcome in both patients groups.

Schramm[1] observed that IOR is not necessarily associated with poor surgical outcome, pointing out that in his study 94.1% of the patients were Hunt and Hess (HH) grades I–III. Sandalcioglu [38] had a similar observation for patients in a good clinical condition. But what about the patients with a poor initial condition and a worse surgical situation? Their observations indicate that IOR has no impact on outcome, neither in patients with good initial condition (HH grades I–III) nor in poor grade patients (HH grades IV and V). Although favorable outcome decreased from 34.6% (9 of 26 patients) to 23.1% (3 of 13 patients) in patients with poor initial condition and mortality increased from 15.4% (4 of 26 patients) to 30.8% (4 of 13 patients) in this group, there was no significant difference in statistical analysis.

In Linderts[51] study new permanent deficits occurred in 21% of IOR cases, which accounted for a rate of 1.8% new neurological deficits (NND) in the total group of patients operated on for cerebral aneurysms. Bertalanaffy [57] et al reported an incidence of 12% NND after IOR compared to 7% in the control group, but GOS was not significantly worsened by this difference. Batjer et al [42, 43] found an increased mortality rate after IOR and confirmed a worsened outcome after IOR in survivors. IOR contributed significantly to fatal outcomes after surgery for ruptured intracranial aneurysm in a report by Yasui. [70] In his study 16 of 63 fatal outcomes after surgery were because of IOR. Others however could not confirm an increased

incident of NND or worsened after IOR in their study groups. [2, 53, 56] These discrepancies may be explained by the fact that outcome measurement by GOS is not a very sensitive improvement. Other factors like SAH, vasospasm may also play a role. However it is uniformly accepted that a true deterioration was observed in patients with IOR during the pre exposure phase.

Leipzig [2] in his extensive review has attempted to correlate outcome with the severity of intraoperative rupture. He observed that of those experiencing a major IOR, one-half sustained a stroke before discharge, and one-third died. The rates of mortality (12.5%) and stroke (28.1%) were substantially less for patients experiencing a moderate IOR. In patients with minor IOR, half recovered without serious deficit. Of note, more than 50% of all patients with IOR in this series experienced a good outcome (without significant deficits). This may reflect the fact that most of the IORs occurred during definitive micro dissection around the aneurysm or with application of the clip. In these circumstances, the hemorrhage usually enters into open subarachnoid spaces, so as not to produce an intraparenchymal hemorrhage or increased intracranial pressure. Significant injury to the patient may more likely be related to suboptimal clip position rather than the direct effect of the IOR.

Rupture during neuroradiological interventions

Not much comparative data is available comparing the risk of rupture during surgery to that during coiling. A risk rate of aneurismal rupture of 2.5% to 5% is generally acceptable during interventional procedures. As with surgery, a history of previous SAH increases the risk for a procedure related rupture of an aneurysm. Similarly, the timing of interventional procedures after SAH does not seem to significantly affect the rate of perforation. However mortality and

morbidity seem to be higher when perforation occurs during an interventional procedure. While Guglielmi et al reported death in more than half of patients with perforation during coil embolization few authors have quoted a risk of mortality ranging from 15% to 33%.

Conclusion

Considered nearly fatal few decades back, intraoperative aneurysm rupture seems to have lost its former high risk and its implication for poor outcome. Current literature review suggests that intraoperative aneurysm rupture has no significant impact on surgical outcome, although a trend to increased morbidity and mortality is observed when IOR occurs in patients with poor initial condition and when rupture occurs in the early preexposure phase.

The occurrence of IOR may never be fully eliminated. By recognizing the situations and circumstances that have bearing on the risk of IOR, the surgeon can anticipate and be better prepared to deal with it. Moreover, a better understanding of the factors associated with IOR can allow for a more considered approach in the surgical decision-making process. Despite all technical advances and surgical skills to manage intraoperative aneurysmal bleeding, one of the key-points of aneurysm surgery remains the avoidance of intraoperative rupture Although IOR of an aneurysm can be a potentially devastating event associated with high morbidity and mortality, the overwhelming majority of IORs occur after the aneurysm has been exposed and are readily managed by the experienced surgeon who has taken appropriate precautions to obtain adequate exposure. The rare intraoperative hemorrhage that occurs before the aneurysm has been exposed is truly devastating.

Techniques that can reduce the risk of IOR include the liberal use of temporary clips and sharp dissection around the aneurysm as opposed to blunt dissection, which transmits pressure to the fragile lesion. Particularly if it is early in the surgeon's experience, there simply is no disadvantage to the use of temporary clipping during final dissection. If ischemia times are kept under safe limits and are managed with contemporary neuroanesthetic techniques, there should be essentially no morbidity associated with the technique. Aneurysms in tight anatomic regions should be managed routinely with early temporary occlusion.

Analysis of results

We analyzed retrospectively the medical records of 378 patients of Anterior communicating artery aneurysms operated at SCTIMST, Trivandrum during period from Jan 1996 to December 2005. Intraoperative aneurysm rupture was encountered in 102 of these cases. This study was confined to the 75 of these cases, whose diagnostic preoperative cerebral angiographic films were available for review. Those factors that might have predisposed to IOR or contributed to a favorable or unfavorable outcome were analyzed in detail.

Factors predisposing to intra operative rupture

This data is analyzed from the records of the operated AcomA aneurysms and compared with the patients having intraoperative rupture (102/378)

Age

Our series does not have enough evidence to suggest that the fragile atherosclerotic vessels of the aged are more prone to get torn off during surgery as has been described by many authors. A higher incidence of intraoperative rupture was not seen in any of the age groups as is seen in the following table. (p value-0.566)

Table 1:

Age	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
AcomA aneurysm with IOR (102)	0	1 (33%)	3 (16.6%)	16 (34%)	31 (24.6%)	42 (32.55%)	07 (14.8%)	0 (28%)	0
AcomA without IOR (276)		2 (77%)	15 (83.4%)	31 (66%)	95 (75.4%)	87 (77.45%)	40 (85.2%)	05 (72%)	01

Sex

Unlike most western series we have found a male predominance in our overall aneurysm series .The same is reflected in this series of 378 anterior communicating artery aneurysms also where males predominate, 243(64.2%) males as compared to 135 (35.8%) females. We did not observe that either sex is more predisposed to IOR as observed in the underlying table (p value-0.230)

Table 2:

Age group	0-50		>50	
	Male	Female	Male	Female
AcomA aneurysm with IOR	38 (53.5%)	13 (41.9%)	33 (46.5%)	18 (58.1%)
AcomA aneurysm without IOR	87 (50.58%)	85 (49.4%)	46 (44.2%)	58 (55.8%)

Preoperative grade

Our hospital policy restricts surgery to good grade (WFNS grade I – II) patients with aneurysmal SAH. Of the 75 patients with intraoperative rupture 69 were in grade I, 4 were in grade II. We had one patient each in grade III and grade four. An interesting observation in our series was that the incidence of IOR was more in grade I patients (30.56%) compared to other grades (10-15%). This however could be erroneous interpretation as majority of our patients were in grade 1(79.6%).

Table 3:

Grade	Total number (IOR)	Without IOR
I	92 (30.56%)	209 (69.44%)
II	08 (15%)	45 (85%)
III	01 (10%)	10
IV	01 (10%)	10
V	00	1
	102	275

Timing of operation

The unique referral pattern of our patients is reflected in the analysis of timing of surgery in relation to the ictus. Twenty-nine patients underwent operation within 4 – 7 days, 22 patients

underwent surgery in the second week, and ten patients in the third and fourth week and one patient were operated late after one month. Timing does not appear to be statistically significant predictor for IOR as is evident in the table.

Table 4:

Duration	No of patients in IOR (IOR rate)	All AcomA aneurysm
1-3 D	06 (12.5)	48
4-7 D	29 (22.4)	129
1-2 W	22 (19.2)	114
2-4W	10 (17.5)	56
1-3 M	01 (12.5)	01
Total	68	356

Previous history of SAH and risk of IOR

Ruptured aneurysms and those with multiple bleeds are known to be more liable for intraoperative rupture. Only eight (10.6%) of our patients gave history of repeated bleeds. In the subgroup of anterior communicating artery patients without IOR, 39 (14.1%) had history of repeated bleeds.

Preoperative hydrocephalus

Retraction of a tight brain is described as an important factor predisposing to IOR. Twenty-five (33%) of our patients who had intraoperative rupture had evidence of hydrocephalus. Of the 276 patients who did not have intraoperative rupture (28 %) has evidence of hydrocephalus. Detailed analysis of the operative notes however failed to establish any link hydrocephalus as a cause for IOR. Similarly release of CSF either from the cisterns or the ventricles, to relax a tense brain also did not seem to predispose to IOR (p value-0.435).

Factors predicting outcome following intraoperative aneurysm rupture-

Outcome was analyzed of 75 patients of anterior communicating artery (Acom) aneurysms who had intraoperative rupture whose diagnostic preoperative cerebral angiographic films were available for review, which was our study group.

Age

Similar to the observation on outcomes of aneurysmal SAH in general, outcome worsened with progressive age though not statistically significant (p value-1.000) (Table 5)

Table 5:

Age	Total number	Excellent	Good	Fair	Poor	Death
< 50 year	36	26(72%)	4	3	0	3(8.3%)
> 50 year	39	22(56%)	11	2	1	3 (7.6%)
	75	48(64%)	15 (20%)	05(6.6%)	01	6(8%)

Sex

As is evident in the table sex of the patient did not have any singular influence on the outcome nor did it influence the risk of IOR (p value-0.321).

Table 6:

Age group	AcomA aneurysm with IOR	
	Males	Females
0-10	0	0
11-20	1	0
21-30	2	1
31-40	12	4
41-50	23	8
51-60	28	14
61-70	04	03
71-80	01	01
81-90	0	0
Total	71	31

Preoperative grade

A Poor preoperative grade is an independent predictor of poor outcome and our study could not establish any link between preoperative grade and IOR in terms of patient outcome (p value-1.000).

Table 7:

The results of surgery as related to the preoperative grade-

Grade	Total number	Excellent (GOS 1)	Good (GOS 2)	Fair (GOS 3)	Poor (GOS 4)	Death (GOS 5)
I	69	47 (68.1%)	11(15.9%)	05 (7.2%)	1(1.4%)	5 (7.2%)
II	04	0	04	0	0	0
III	01	01	0	0	0	0
IV	01	0	0	0	0	1
V	00	00	0	0	0	0
	75	48(64%)	15 (20%)	05(6.6%)	1	6(8%)

Timing of surgery following ictus

The timing of operation following the ictus and its relation to postoperative outcome is shown in the following table 8. Interesting observation in this series is that patients operated towards the latter half of the first week were more likely to have unfavorable outcome (3 out of 29 patients died and one had a poor outcome -13.7%) (Pearson chi-square 0.094). Patients operated after two weeks has good outcome in 91%.

Table 8:

DAYS	OUTCOME (%)				
	Excellent	Good	Fair	Poor	Death
1-3 D (6)	4 (66.6)	1(16.6)	0	0	1(16.6)
4-7 D (29)	18 (62)	7 (24.1)	0	1(3.4)	3 (10.3)
1-2 W (22)	12 (54.5)	5 (22.7)	4(18.1)	0	1 (4.5)
2-4W(10)	8 (80)	2 (20)	0	0	0
1-3 M (1)	0	0	1	0	0

Multiple bleeds and outcome

Outcome in patients with multiple rebleeds, however was similar was similar to the rest of the series and a history of multiple bleeds does not adversely affect outcome (p value-0.657).

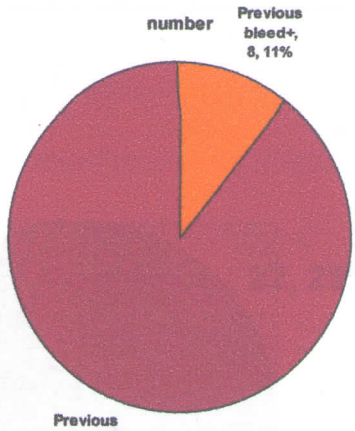


Table 9:

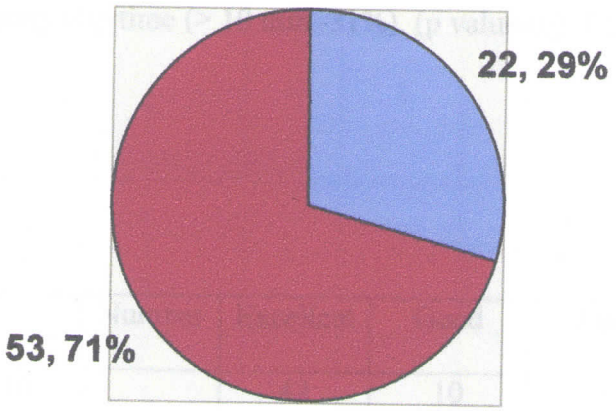
	outcome				
	Excellent	Good	Fair	Poor	Death
Total 08	05(62.5%	02(25%)	0	0	1(12.5%)

Hydrocephalus

Influence of hydrocephalus and preoperative grade on outcome is highlighted in the following table. Outcome of patients with hydrocephalus and IOR appears to be similar to the rest of the patients in the series (p value-0.519).

Table 10:

Hydrocephalus	PREOP GRADE					OUTCOME (%)				
	I	II	III	IV	V	Excellent	Good	Fair	Poor	Death
Yes	22	2	0	1	0	14(56)	6(24)	1(4)	1(4)	3(12)



Size of aneurysm

Our series did not have any giant aneurysm and majority of the patients had small aneurysms (60 patients). Size does not seem to predispose to intraoperative rupture, however it does adversely affect outcome with patients having large aneurysms faring much worse compared to those with small aneurysm (poor outcome 34% compare to twelve percent). Control of the bleeding following rupture is apparently more difficult with larger aneurysm as is evident by longer temporary clip time (> 10 min -31%). (p value-0.116).

Table 11:

Size	Number	Excellent	Good	Fair	Poor	death
Small(5-10 mm)	60	43 (71.6%)	10 (16.6%)	3 (5%)	1 (1.6%)	3 (5 %)
Large(11-25 mm)	15	5 (33%)	5 (33%)	2 (14%)	0	3 (20%)

Table 12:

	Small size					Large size				
Time	Excellent	Good	Fair	Poor	Death	Excellent	Good	Fair	Poor	Death
0-2 min(6)	4	-	1	-	-	-	1	-	-	-
2-5 min (28)	17	4	-	1	-	4	1	1	-	-
5-10 min(13)	10	1	-	-	1	-	0	1	-	-
10-30 min(11)	4	2	-	-	2	1	2	-	-	-
>30 min (5)	2	1	-	-	-	-	1	-	-	1
Total	37 (74%)	08 (16%)	01 (2%)	01 (2%)	03 (6%)	05 (38.4%)	05 (38.4%)	02 (15.3%)	-	01 (7.6%)

Vasospasm and surgical outcome

Vasospasm, however has a negative effect on overall outcome independent to IOR and the same was observed in our series (p value-0.116) and also as seen in following table.

Table 13:

Vasospasm	PREOP GRADE					OUTCOME					
No.	I	II	III	IV	V	GOS I	II	III	IV	V	TOTAL
28	24	03	0	1	0	14 (50%)	07 (25%)	03 (10.7%)	1 (3.5%)	3 (10.7%)	28

Multiple aneurysms and outcome

Out of 75 patients of Acom aneurysm with intraoperative rupture, 11 (14.6%) patients harbored multiple aneurysms (15 aneurysms). Out of these 8 had two aneurysms, 2 patients had three aneurysms, 1 had four aneurysms. Outcome according to number of aneurysms postoperatively shows that multiplicity does not influence outcome significantly. (p value-0.657)

Table 14:

GOS	2 Aneurysms	3 Aneurysms	4 Aneurysms
I (63.6%)	04	2	1
II (18.1%)	02	0	0
III	0	0	0
IV	0	0	0
V (18.1%)	02	0	0
Total	8	2	01

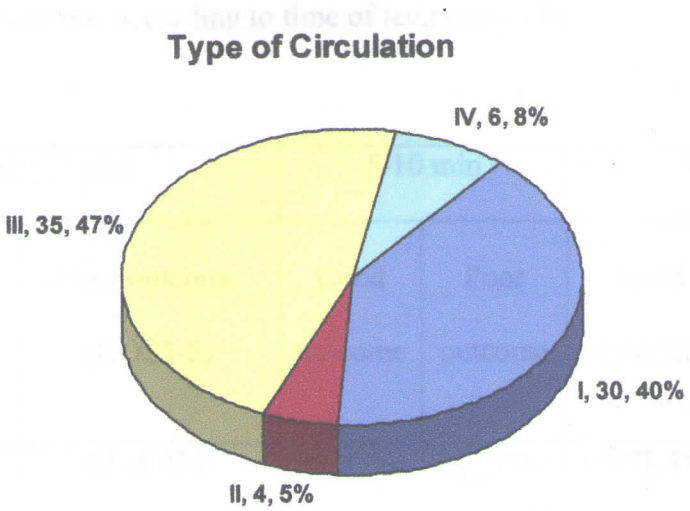
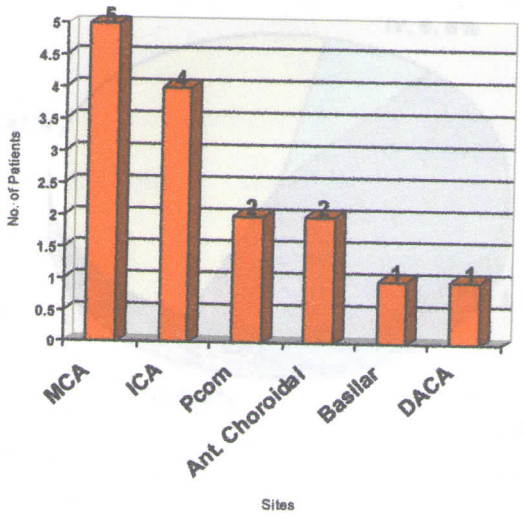


Table 15:

Type	Excellent	Good	Fair	Poor	Death
I (30)	18 (60%)	04 (13.3%)	O3 (10%)	1 (3%)	4 (13.3%)
II (04)	2 (50%)	2 (50%)	0	0	0
III (35)	24 (68.5%)	8 (22.8%)	1 (2.8%)	0	02 (5.7%)
IV (06)	04 (66.6%)	1 (16.6%)	1 (16.6%)	0	0

Site Of multiple aneurysm(N=15)



Type of circulation and outcome

Of the seventy five patients with intraoperative rupture 30 (40%) had a Type I circulation, 4 (5.3 %) had a type II circulation, 35 (46.6 %) had a type III pattern and six (8 %) had a type IV pattern. The relatively higher incidence of adverse outcome seen in Type I and type III circulation appears to be directly linked to the fact that more number of patients with these circulatory patterns required longer periods of temporary clip application (p value-0.128).

Type of circulation and outcome according to time of temporary clip.

Table 16:

Type	Time < 5 min		5-10 min		> 10 min	
	Good outcome (GOS 1-2)	Poor outcome (GOS3-5)	Good outcome	Poor outcome	Good outcome	Poor outcome
I	11(91.6%)	01 (8.4%)	04(80%)	01(20%)	05(71.4%)	02(28.6%)
II	02	0	-	-	02	0
III	17 (94.4%)	01 (5.6%)	06	0	06(85%)	01(15%)
IV	02	0	02	0	--	-

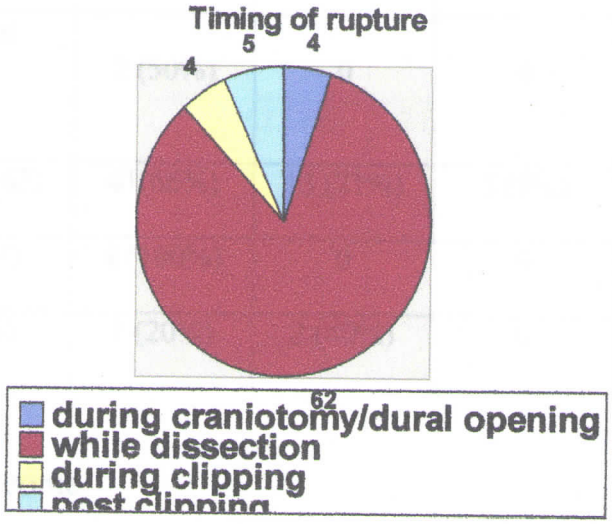
Timing of rupture

Timing of rupture and Projection

Of the four patients who had aneurismal rupture during craniotomy or dural opening, two had an anteroinferior projection while two had an anterosuperior projection. Intraoperative rupture during dissection is most common with anterior projections either anterosuperior or anteroinferior. IOR during clip application is relatively less common and occurs more frequently with an anteroinferior projection.

Table 17:

Stage of rupture	Superior	Anterior	Inferior	Posterior	AS	PI	AI	PS
Craniotomy/dural opening	0	0	0	0	2	0	2	0
While dissection	6	13	9	0	15	1	17	1
While clipping	1	0	0	1	0	0	2	0
After clipping	1	0	2	0	0	1	1	0



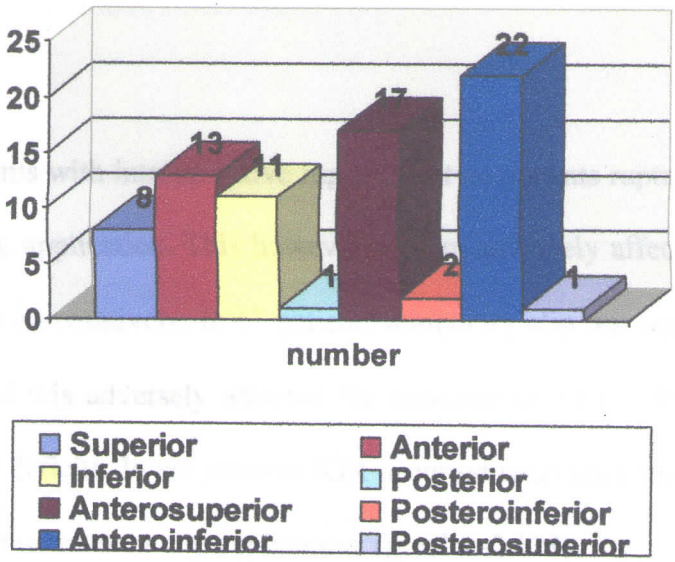
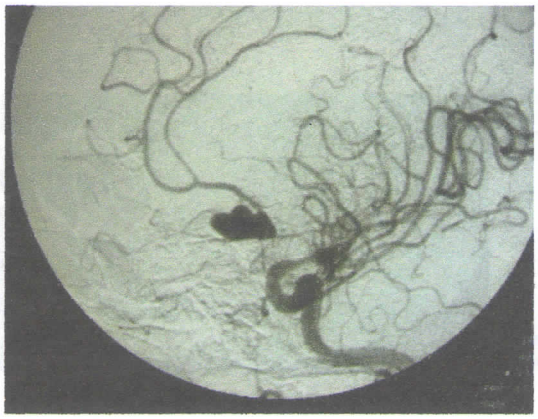


Table 19:

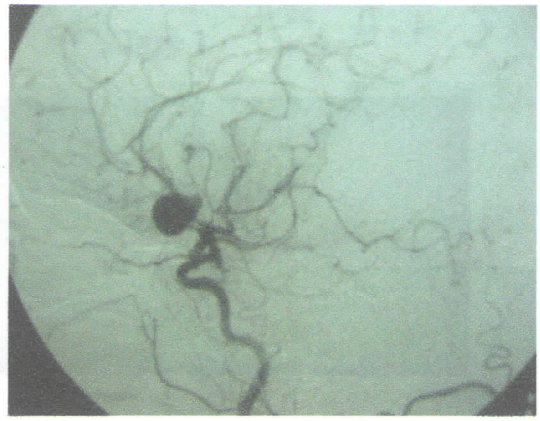
Projection	No.	Excellent	Good	Fair	Poor	Death
Superior	8	5 (62.8%)	2 (25%)	1(12.5%)	0	0
Anterior	13	8 (61.5%)	4 (30.7%)	0	0	1 (7%)
Inferior	11	8 (73%)	0	1 (9%)	0	2 (18%)
Posterior	1	1 (100%)	0	0	0	0
Anterosuperior	17	9 (53%)	4 (23.5%)	2 (11.7%)	0	2 (11.7%)
Posteroinferior	2	1 (50%)	0	1(50%)	0	0
Anteroinferior	22	15 (68%)	5 (23%)	1(4.5%)	0	1(4.5%)
Posterosuperior	1	1 (100%)	0	0	0	0

Projection of aneurysm

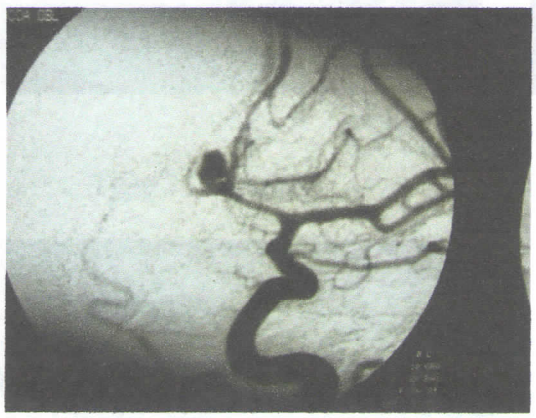
Anterior projection



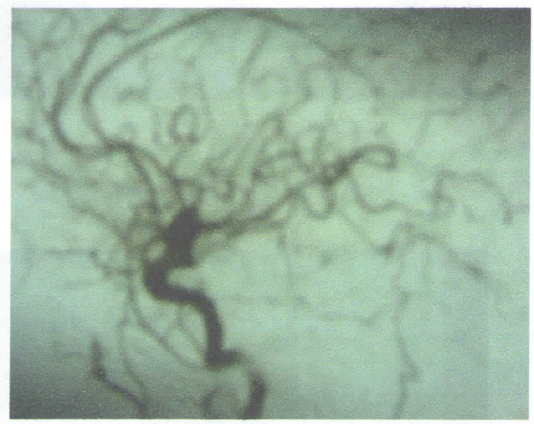
Anteroinferior projection



Anterosuperior projection



Inferior projection



Timing of rupture and outcome

Of the four patients who had an IOR in the predissection early phase two did well while the other two expired. IOR's occurring during the other stages of aneurysm surgery does not appear to affect outcome significantly as is seen in table.

Table 18:

Stage of rupture	Excellent	Good	Fair	Poor	Death
Craniotomy/dural opening	2 (50%)	0	0	0	2 (50%)
While dissection (62)	41(66%)	13 (21%)	5 (8%)	0	3 (5%)
While clipping (4)	4 (100%)	0	0	0	0
After clipping (5)	1 (20%)	2 (40%)	0	1(20%)	1 (20%)

Projection and outcome

Of the six mortality recorded in this series, two had an inferior projection and two had an anterosuperior projection. An anterior projection was seen in one and an anteroinferior projection was seen in the last patient. Poor outcome was noted in inferior and anterosuperior projecting aneurysm, which was 27% and 23 % respectively as compare to 9-13% poor outcome in other projections (p value-0.116).

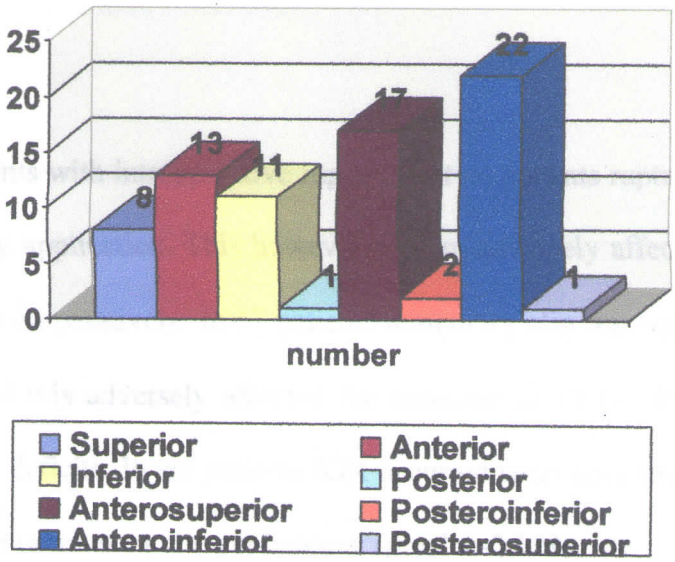


Table 19:

Projection	No.	Excellent	Good	Fair	Poor	Death
Superior	8	5 (62.8%)	2 (25%)	1(12.5%)	0	0
Anterior	13	8 (61.5%)	4 (30.7%)	0	0	1 (7%)
Inferior	11	8 (73%)	0	1 (9%)	0	2 (18%)
Posterior	1	1 (100%)	0	0	0	0
Anterosuperior	17	9 (53%)	4 (23.5%)	2 (11.7%)	0	2 (11.7%)
Posteroinferior	2	1 (50%)	0	1(50%)	0	0
Anteroinferior	22	15 (68%)	5 (23%)	1(4.5%)	0	1(4.5%)
Posterosuperior	1	1 (100%)	0	0	0	0

Of the 75 patients with intraoperative rupture, in two patients rupture occurred in spite of elective temporary clip application. This however did not adversely affect the outcome as both the patients did well postoperatively. In 67 patients temporary clip was applied as an emergency salvage procedure and this adversely affected the outcome as 12 (17.9%) of them developed ischemic neurological deficits. In six patients IOR occurred soon after the final dissection and it was managed by direct permanent clip application. (p value-0.128).

The inadequacy of such emergent clip application is evident in the following table as three (50%) of these patients developed ischemic deficits.

Table 20:

	Number of patients	Ischemic deficits
Elective temporary clip	2	0
Emergency temporary clip	67	12 (17.9%)
Direct permanent clip	6	3 (50%)

Of the 67 patients who underwent emergency clip application available data as regard to time of temporary clip was available in 63 patients. As is obvious from the underlying table more number of adverse outcomes was seen as the duration of temporary clip application increased.

Temporary clip, duration and outcome

In 67 patients temporary clip was applied as an emergency salvage procedure and this adversely affected the outcome as 12 (17.9%) of them developed ischemic neurological deficits. As regards to duration of temporary clip 65% infarcts were observed when the clip application exceeded 10 minutes.

Table 21:

Time	Excellent	Good	Fair	Poor	Death	Infarct
0-2 min (6)	4 (67%)	1(16.6%)	1(16.6%)	0	0	1(16.6%)
2-5 min (28)	21 (75%)	5(17.8%)	1 (3.5%)	1(3.5%)	0	3(10.7%)
5-10 min (13)	10 (77%)	2(15.3%)	0	0	1 (7.6%)	2(15.3%)
10-30 min (11)	5 (45.4%)	4(36.3%)	0	0	2(18.1%)	5(45.4%)
>30 min (5)	2 (40%)	2 (40%)	0	0	1 (20%)	1 (20%)

Temporary clip duration and projection

We had observed that anterior projecting aneurysms has temporary clip application time > 10 min for 38% patients followed by anteroinferior and anterosuperior 28% and 27% respectively. (p value-0.550).

Table 22:

Projection	0-2 min	2-5 min	5-10 min	10-30 min	>30 min
Superior	1	4	0	1	0
Anterior	0	4	4	4	1
Inferior	0	4	3	1	0
Posterior	0	1	0	0	0
Anterosuperior	1	6	3	2	2
Posteroinferior	0	1	0	0	0
Anteroinferior	3	7	3	3	2
Posterosuperior	0	1	0	0	0

Temporary clip duration and timing of IOR

Table 23:

Stage of rupture	Timing of clip					
	0-2 min	2-5 min	5-10 min	10-30 min	>30 min	Total
Craniotomy/dural opening	0	2	0	2	0	4
While dissection (62)	5	20	14	09	5	53
While clipping (4)	1	3	0	0	0	04
After clipping (5)	0	3	0	0	0	03

Follow up

63 (91%) patients available for follow up at one year and at three year and five year follow up dropped to 67% and 46% respectively. 49 patients were totally independent for activities of daily life (GOS-1), 9 patients were moderately disabled but independent (GOS-2) and 5 patients were severely disabled and totally dependent on others for their daily activities (GOS-3).

Table 24

Follow up	Yes	No	percentage
1year	63	06	91%
3 year	34/51	17	66.6%
5 year	17/37	20	45.9%

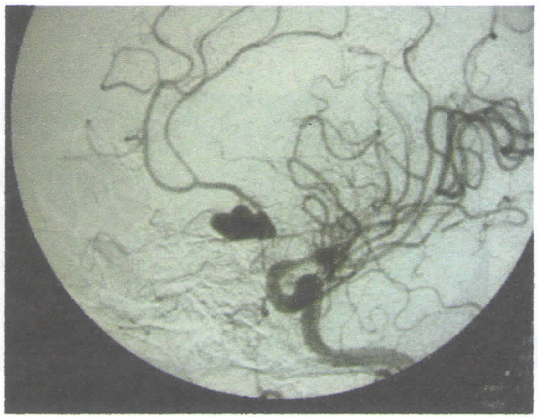
Glasgow outcome score during follow up

Table 25

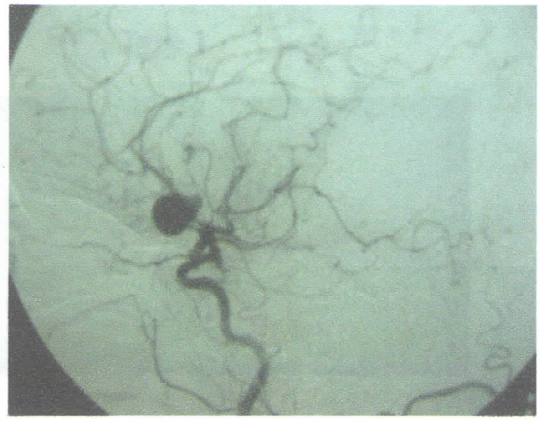
Follow up	GOS 1	GOS 2	GOS 3	GOS 4
1 year	49	9	05	0
3 year	27	5	02	0
5 year	13	3	01	0

Projection of aneurysm

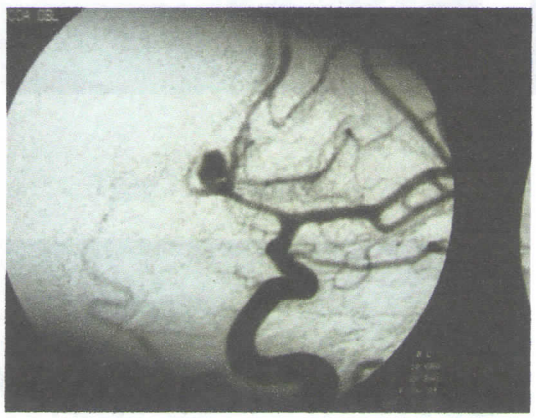
Anterior projection



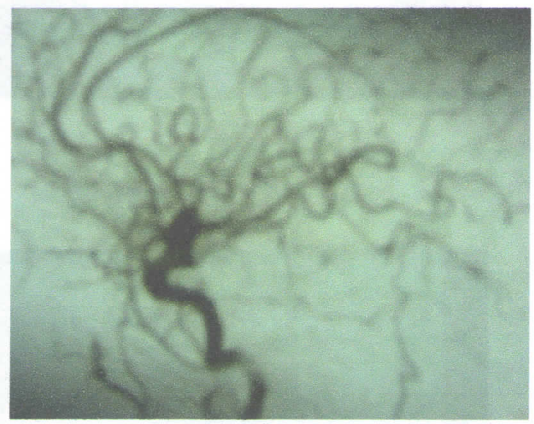
Anteroinferior projection



Anterosuperior projection

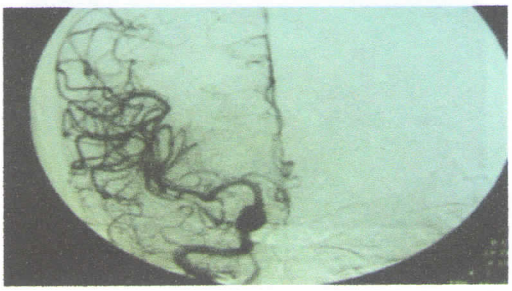


Inferior projection

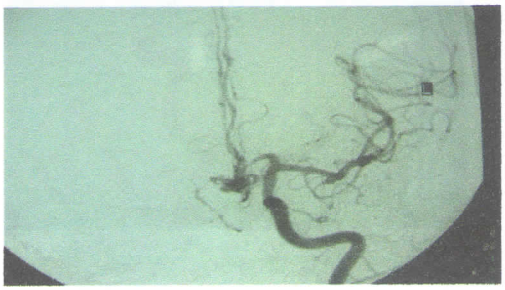


Types of circulation

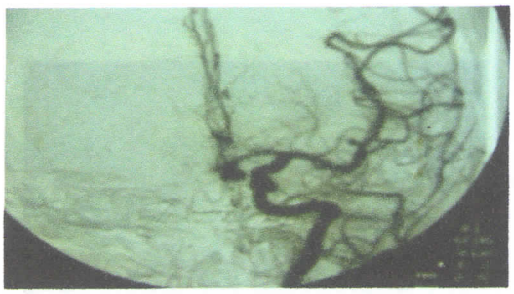
Type 1



Type 1



Type 2



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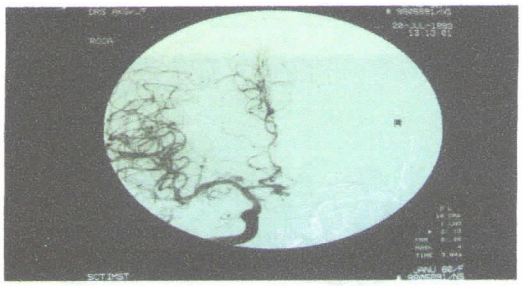
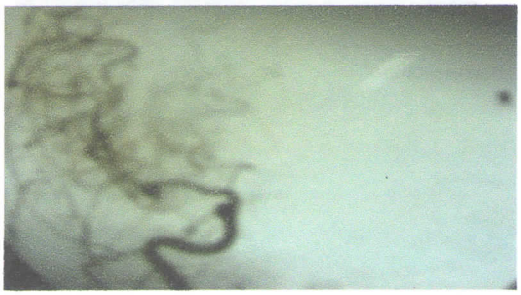
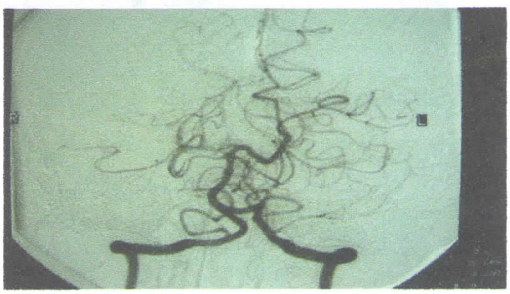


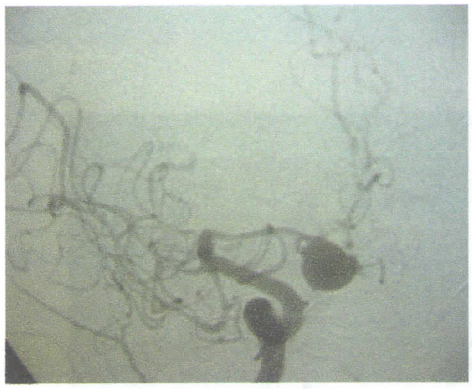
Type 3

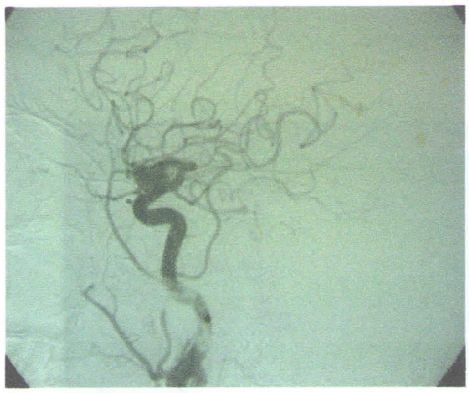


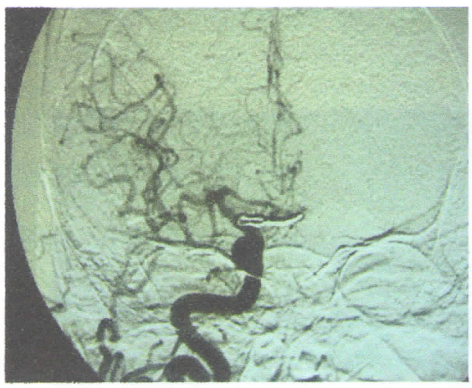
Type 4

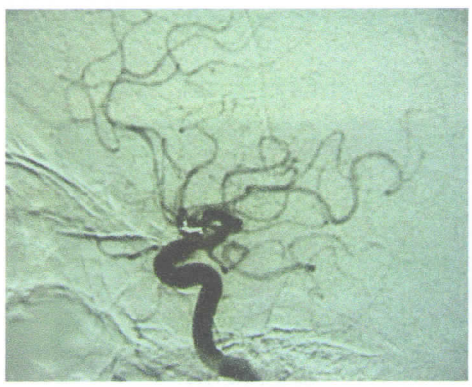


Preoperative and post clipping DSA



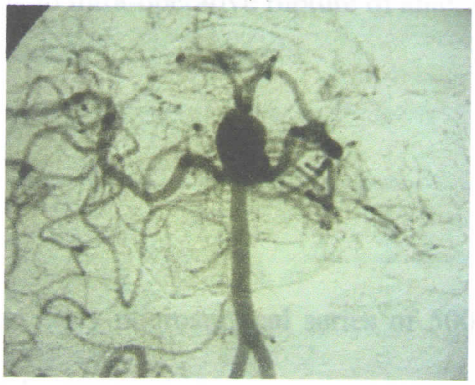


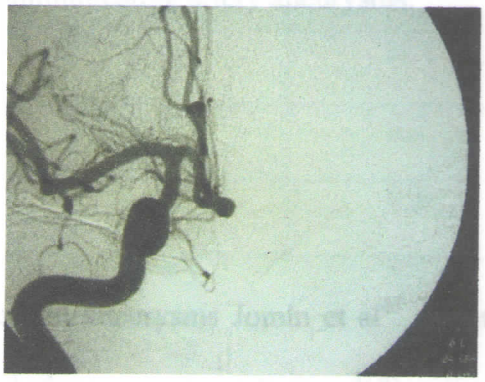


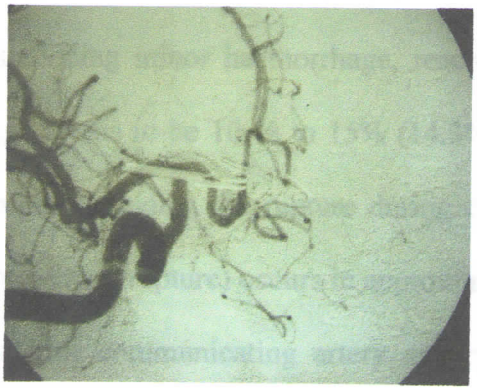


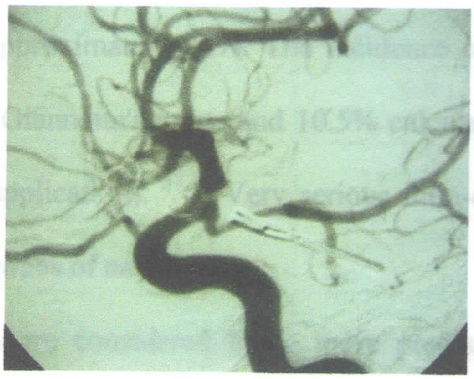
Preoperative and post clipping DSA of multiple aneurysms

(Basilar top and Acom A)









Discussion

In comparison to the innumerable amount of literature available on various aspects intracranial arterial aneurysms there are surprisingly few papers on the incidence and factors predisposing to intra-operative rupture of anterior communicating artery aneurysms.

Incidence

In an early microsurgical series of 500 operated aneurysms Jomin et al[47] reported that approximately 20% of the aneurysms ruptured during operation. Batjer [42,43] recorded an incidence of 45%, whereas Giannotta [37] reported an incidence of 14.3%. More recently, IOR rates have ranged between 15 and 50%, [1, 37, 39, 42,43 ,48,49] although several series report much lower incidence. [50,51] When we summarize available data, the incidence of all intra-operative ruptures including minor haemorrhage, reaches approximately 20%. The incidence of serious hemorrhage seems to be 10 % to 15% (14.3% in Giannotta's paper and 10.5% calculated from Batjer's paper excluding the rupture during clip application). [37,42] Very serious intra-operative rupture (premature rupture) occurs in approximately 5% of cases.

Anterior communicating artery aneurysms are considered to be more predisposed to intraoperative rupture by many authors. Leipzig et al [2] in their extensive analysis of 1694 aneurysms with intraoperative rupture had a similar observation in following table.

Rate of intraoperative rupture by aneurysm location- Leipzig[2] series

Location	No of aneurysms (%)	NO of IOR	IOR rate	% of total number
MCA	409(24.10	26	6.4	23
AcomA	387 (22.8)	36	9.3	31.9
PComA	307 (18.1)	28	9.1	24.8
Ophthalmic	110 (6.5)	3	2.7	2.7
Basilar apex	101(6)	1	1	0.9
Ant. Choroidal	67(4)	3	4.5	2.7
Pericallosal	64(3.8)	1	1.6	0.9
ICA bifurcation	57(3.4)	2	3.5	1.8
Paraclinoid	56(3.3)	1	1.8	0.9
PICA	45(2.7)	7	15.6	6.2
SCA	24(1.4)	0	0	0
Basilar trunk	22(1.3)	1	4.5	0.9
ICA	20(1.2)	2	10	1.8
PCA	13(0.8)	1	7.7	0.9
Ant. cerebral	5(0.3)	0	0	0
VA	4(0.2)	0	0	0
AICA	3(0.2)	1	33.3	0.9
Present series AComA	378	102	26.9	-

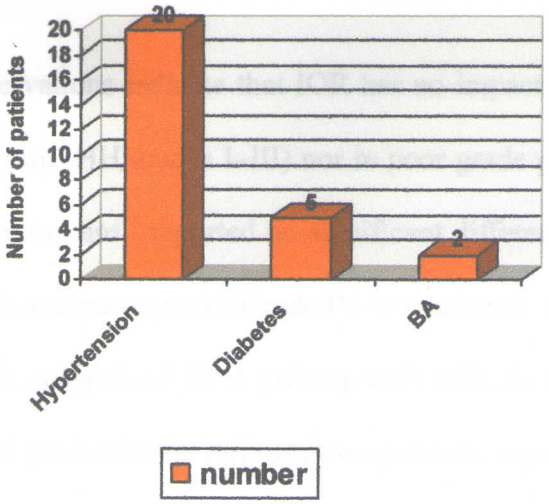
Yasargil [26] in his series of Acom Artery aneurysms presents an incidence of 24% intraoperative rupture. In present series of the total 378 patients operated for an anterior communicating artery aneurysm during the last ten years in our institute 102 patients has evidence of intraoperative rupture, an incidence of 27% which is almost similar to most of the series available in literature. [1, 26, 37,39,42,43,45,48,49]

Patient characteristics-

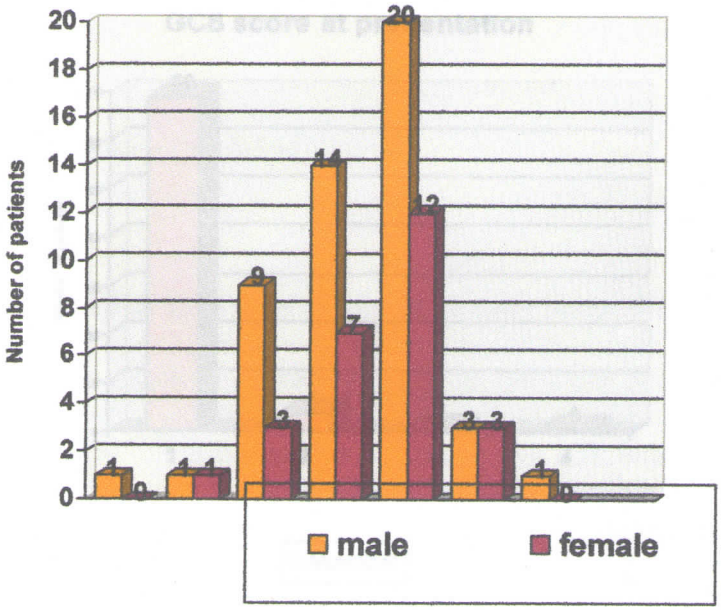
Except in the pediatric population aneurysms in general are known to be more common among females. Although literature mentions no correlation between sex and the incidence of intra operative rupture, in our series intraoperative rupture was found to be more common among males. This probably is related to the fact that unlike in western series we have a male preponderance in our aneurysm population. Similarly old age, which is independently considered to be a poor prognostic factor for overall outcome, does not appear to influence the risk of intraoperative rupture (p value-0.566).

Our observations are similar to those in the available literature where, apart from hypertension other co morbid factors seldom predispose to intraoperative rupture

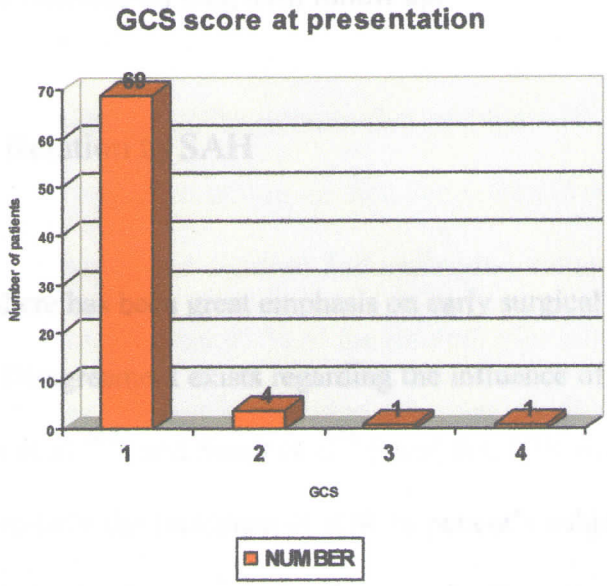
Co-morbid conditions

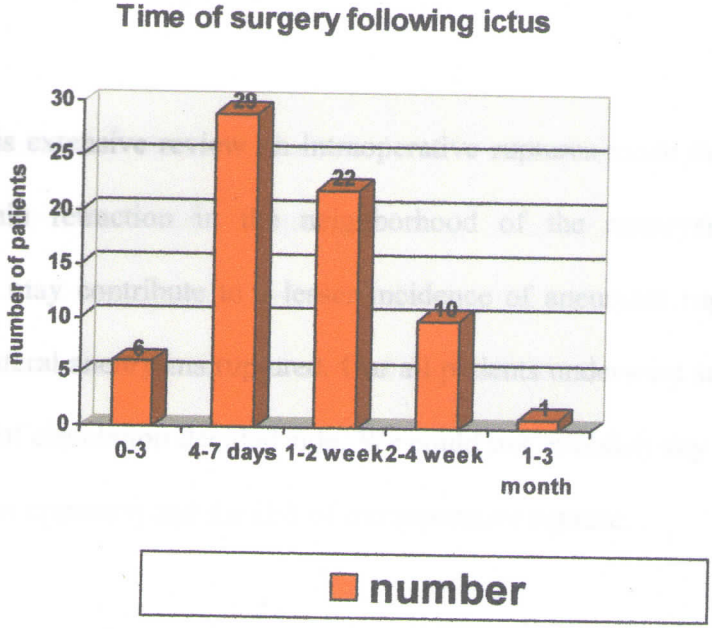


Age and sex distribution of patients (n-75)



Observations indicate that IOR has no impact on outcome, neither in patients with good initial condition (HH grades I–III) nor in poor grade patients (HH grades IV and V). Le Roux et al [39,40] and Schramm [1] reported no significant difference in the rate of IOR between good-grade (Grade I–III) and poor-grade (Grade IV–V) patients. Leipzig2 has made a similar observation in his extensive analysis of 1694 patients with IOR. In the present series 73 patients (see table 8) were in good grade (Grade I–II) and two patients in poor grade (Grade 3-4). Our conclusion is in accordance to the general consensus that although preoperative grade does not influence the risk of intraoperative rupture, it does have a negative effect on overall outcome independent to its role on IOR.





Number of days between SAH and surgery as well as intraoperative rupture rate for AComA aneurysms- (present series)

Days between SAH and surgery	No of aneurysms	No of IOR	IOR rate
0-3 days	48	6	12.5
4-7 days	129	29	22.4
1-2 week	114	22	19.2
3-4 week	57	10	17.5
> 1 month	8	01	12.5

Multiple rebleeds

The IOR rate for aneurysms with confirmed multiple rebleeds was more than three times that of the overall IOR rate in Leipzig's[2] series and one-quarter of all major IORs occurred in aneurysms with multiple SAH (suspected or confirmed). These composed 3.5% of Leipzig's series[2], compared with 29% of patients in the series reported by Sundt et al[54]. Van Lindert [51]made a similar observation where unruptured aneurysms were found to have considerably lower rates of IOR than ruptured aneurysms (only 1.1% in their series). In present series we could not establish the influence of multiple rebleeds on IOR as only eight of our total 75 patients (10.6%) gave a history of previous subarachnoid hemorrhage (see table 9). However history of multiple rebleeds did not seem to influence the outcome as seven of these eight patients (87%) had a good outcome on long term follow up.

Timing of Surgery in Relation to SAH

Since the 1980s, there has been great emphasis on early surgical intervention to minimize the risk of rebleeding [70]. Disagreement exists regarding the influence of the timing of surgery on IOR. Studies by Le Roux et al [39,40] and Sundt et al[54] found that IOR was unrelated to the timing of surgery after SAH. Similarly the incidence of IOR in patient's subjected to early versus late operation has been reported to be the same for both groups by Kassell et al.[53]In previous studies, early surgery have been reported to be associated with a higher incidence for IOR. [1,56,59] Schramm [1] found an increased IOR rate with early surgery (within 72 hrs after bleeding) with a fourfold higher IOR rate. In their study Schramm [1] concluded that the higher incidence of IOR in

early surgery is due to a higher fragility of the clot occluding the rupture site and /or the aneurysmal sac. Lindert[51] found an increased incidence of IOR when surgery was performed in the first 48 hrs after bleeding; although significance was not reached. Sandalcioglu [38] observed that whereas the time of surgery showed no influence on the risk of IOR, early surgery seems to be weakly associated with an increased risk of unfavorable outcome as an independent factor. Similarly, in Leipzigs[2] study, the average IOR rate for surgery performed 0 to 3 days after SAH was not remarkably different from the average IOR rate for surgery performed more than 3 days after SAH. However in their study surgery performed during the first 2 weeks after SAH compared with surgery performed later than 2 weeks, there seemed to be a reduction in the IOR rate after the second week. The IOR rate dropped from 11.2% during the first 2 weeks after SAH to only 5.4% thereafter. Overall, it seems that the timing of surgery in the first two weeks after SAH has little effect on the probability of an IOR. However, delayed surgery may decrease the risk of IOR.

In the present series (table 8) of the seventy-five patients with IOR, fifty-seven patients (84%) patients had undergone operation within the first two weeks (6 within 1-3 days, 29 within 4-7 days and 22 within 1- 2 week) and eighteen had undergone surgery after two weeks of the ictus. An interesting observation was that 91 % of the patients who underwent surgery later than two weeks had a good outcome whereas in the other subgroup which underwent surgery within two weeks, good outcome was seen in 82 % suggesting indirectly that outcome are better with delayed surgery (Pearson chi square 0.094). This finding is however independent of its effect on IOR. Sandalcioglu [38] in accordance with the observation makes our data that early surgery seems to be weakly associated with an increased risk of unfavorable outcome as an independent factor.

Approach

Lindert [51] in his extensive review on intraoperative ruptures made this observation that the avoidance of brain retraction in the neighborhood of the aneurysm by choosing a contralateral approach may contribute to a lesser incidence of aneurysm rupture. In his study none of the 28 contralateral aneurysms ruptured. Our all patients underwent surgery by pterional approach and the type of circulation decided side. We could not establish any influence between side of approach, type of approach and the risk of intraoperative rupture.

Size and outcome in IOR

Although Sluzewski et al [60] documented that smaller aneurysms tended to have a higher rate of perforation, most authors agree that the size of the aneurysm does not seem to influence IOR rate. In Linderts [51] series none of the giant aneurysm ruptured during surgery. This has been confirmed in other studies [62]as well with the exception of Sundt [54] who found an increased rate of IOR in giant aneurysms.

In the present series (Table 11 & 12) intraoperative rupture was found to be more common in small aneurysms (80%) as compared to large and giant aneurysms (twenty percent). This does not appear to influence the outcome as nearly 88% of patients with small aneurismal rupture had a good outcome 88% (GOS 1 and 2). However IOR during surgery for large aneurysms is associated with a negative influence with nearly one third of the patients having a poor outcome in thirty three percent (p value-0.116).

Multiple aneurysms -

In his series Yasargil [26] observed that nearly 12% of ruptured anterior communicating artery aneurysms were associated with multiple aneurysms. In our present series (table 14) out of the 75 patients of Acom aneurysm with intraoperative rupture, 11 (14.6%) patients harbored multiple aneurysms (15 aneurysms). Out of these 8 had two aneurysms, 2 patients had three aneurysms, 1 had four aneurysms. A middle cerebral artery aneurysm was associated with ACOM in 05 patients (thirty six percent). Other locations included ICA (4), posterior communicating artery (4), anterior choroidal (2) , and basilar top two. An interesting observation from in the present series is that the mortality rate was higher for multiple aneurysms (18%) as compared to overall mortality rate (8 %). The exact mechanism for this unfavorable outcome was not evident in our series, but does not appear to be linked to the intra operative rupture of the anterior communicating artery aneurysm (p value-0.657).

Vasospasm and outcome-

Available literature is limited on the role of vasospasm in intraoperative rupture and its role is inconclusive. However the presence of vasospasm has a negative impact on the overall outcome independent to its effect on intraoperative rupture. The incidence of vasospasm in the subgroup of patients who did not have intraoperative rupture and influence of spasm on intraoperative rupture could not be established. As has been observed in literature the presence of vasospasm affects the outcome adversely, with only 75% of patients with spasm having a good outcome compare to 84% without vasospasm (Table 13).

Timing of IOR in Surgery

Yasargil [26,49] was the first to point out that rupture occurred most usually during a) retraction of the brain b) dissection of the parent vessels of the aneurysm c) direct mobilization of the aneurysm .The time of IOR was further divided into five main time periods by Leipzig[2]: predissection, Initial micro dissection, definitive micro dissection, clipping, and post clipping.

As described by Saito et al [62] and Batjer and Samson [42,43], the vast majority (85.8%) of IOR s occurred during surgical manipulation around the aneurysm.

In present series (table 18) sixty-two (82.6%) patients had rupture during dissection and nine (12%) during clip application or manipulation. Timing of the rupture however did not influence the outcome as is evident in the following table (p value-0.197)

Correlation between Outcome and intraoperative rupture timing

Timing of rupture	Excellent/Good (GOS 1-2)	Poor/death (GOS 3-5)
Craniotomy/dural opening (4)	2 (50%)	2 (50%)
While dissection (62)	54 (87%)	8 (13%)
While clipping (4)	4 (100%)	0
After clipping (5)	3 (60%)	2 (40%)

Very early premature ruptures like the ones, which happen during induction of anesthesia or dural opening, seem to be unavoidable since they had nothing to do with surgical techniques.

Fortunately these types of premature ruptures are extremely uncommon and very few authors have reported them. Houkins [50] mentions 5 cases (21% of premature ruptures and 1.3% of all cases) of very early premature rupture prior to the substantial dissection of the aneurysm which was induced by simple opening of the dura mater and arachnoid membrane .As analyzed in his study, the outcome was poor in these cases. In Leipzig series[2], IOR occurred in the predissection phase in 5.3% of aneurysms. This corresponds to the rate of 0.62 to 8.3% reported in other studies [2, 37, 52, 53, 54] and reemphasizes the necessity of careful technique for induction of anesthesia. Present series (table 17,18, 23) has 4 cases (5.3%) of rupture during craniotomy or dural opening (predissection phase). Of these two patients (50%) has poor outcome. This corresponds to the rate of 0.62 to 8.3% reported in other studies [2, 36, 37, 52, 53, 54] and reemphasizes the necessity of careful technique for induction of anesthesia.

Temporary clipping

In 1986, Ausman and Diaz [55] commented that the use of temporary occlusion in the surgical treatment of intracranial aneurysms significantly reduced the incidence of IOR. Several subsequent studies also reported the use of temporary occlusion to decrease IOR. Duration of temporary clipping was of decisive importance whether neurological deficits occurred or not. Permissible artery occlusion times may differ but temporary clipping is generally regarded as safe for 10 – 20 minutes with cerebroprotective measures and in individual cases even for a longer period [68,69].

Leipzig[2] observed that that aneurysms treated without temporary occlusion had more than twice the rate of IOR compared with aneurysms treated with temporary occlusion. Similarly

ruptured aneurysms were temporarily occluded more often than unruptured lesions. There were no IOR in surgery for unruptured aneurysms treated with temporary occlusion in Leipzig's series[2].

In present series (Table 20 & 21), only 2 patients underwent rupture following elective temporary clipping whereas in the rest 67 patients temporary clipping was applied as a salvage measure following intraoperative rupture. A statistical correlation is difficult to establish between these two groups as the first group has only two patients. Duration of Temporary clipping varied, but 47 (74.6%) patients had a temporary clip time of less than 10 minutes. Outcome correlated inversely with the duration of Temporary clipping (p value-0.357). Poor outcome was observed in 18.75% of the patients with a temporary clip application time of more than 10 min whereas the outcome was poor in only 8% when the temporary clip application time was less than 10 minutes.

Type of circulation

Yasargil [26], Le Roux [17] have shown in their series that in patients with Anterior communicating artery aneurysms, more than 50% of patients had type III dominant circulation. The present series shows this incidence to be 46.6% (table10). As regards to outcome Ozdemir G et al [71] found that type I and II circulations fared better than type III and IV. In present series (Table 15 & 16) rupture was most commonly associated with type III circulation 46.6% followed by type I (40%). However this was not linked to an unfavorable outcome as poor outcome was seen more often with type I-16.6% as compared to type III- six percent.

Authors differ in their findings on anterior communicating artery aneurysm projections. While VanderArk and Kempe[25], Norlen and Barnum[23] feel that the inferiorly projecting aneurysms are most common, Yasargil [26] series has posterior projection as the commonest (34%) followed by superior 22.7%. Nathal E et al [27] noted aneurysms located between the bilateral A2 portions of the ACA as the commonest projection (Type-2 posterior, 58.9%). In the present series an anterior projection was found to be more common with 17.3% having a pure anterior projection, 29.3% having an anteroinferior and 22.6% having an anterosuperior (22.6 %) projection (Table 19).

Francois Proust et al [72] observed significantly higher proportion of vessel occlusion was found between type two aneurysms (posterior 58.9%). They also analyzed vessel occlusions and post procedural rebleeding on account of the projection of aneurysms. For anteriorly projecting aneurysms (Type 1), the proportion of parent vessel occlusion after microsurgical treatment decreased from 11.1% for the 1990 to 1995 period to 0% for the 1996 to 2000 period. For posteriorly projecting aneurysms (Type 2), the proportion of parent vessel occlusion after microsurgical treatment decreased from 31.6% for the 1990 to 1995 period to 16.7% for the 1996 to 2000 period. Post procedural rebleeding only occurred in cases of posteriorly projecting aneurysms (two cases). Jha et al [73] observed most of the posterosuperior pointing aneurysms presented in poorer grades and outcome was unsatisfactory. In comparison most of the anteroinferior pointing aneurysms presented with better grades and results were satisfactory.

Yasargil [26] observed that projection of fundus is an important factor-predicting outcome. Anterior, superior and posterior projecting aneurysms had good results of 93.7%, 91.8% and

88.4% respectively, while patients with inferiorly projecting aneurysms had only 79.2 % good results. In present series (table 19, 22) anteriorly projecting aneurysms (anterior and anteroinferior) were more frequently seen to bleed intraoperatively (46.6%), but unfavorable outcome (Glasgow outcome score– GOS 3-5) was observed more frequently in superior (superior and anterosuperior-20%) and inferior (27%) projections (p value-0.116).

Out of four patients who had premature rupture (5.3%) during craniotomy or dural opening (predissection phase) – projection of aneurysm was anteroinferior and anterosuperior in two patients each.

Outcome in Patients with IOR

Whether the occurrence of IOR has an influence on outcome is still controversial. Several authors have addressed outcome in patients with IOR [1, 41, 50, 51] compared with those without IOR. There is general agreement that appropriate maneuvers to control IOR together with the surgeon's experience, now days affect a similar outcome in both patients groups. Bertalanaffy et al [57] reported an incidence of 12% NND after IOR compared to 7% in the control group, but GOS was not significantly worsened by this difference. Batjer et al [42,43] found an increased mortality rate after IOR and confirmed a worsened outcome after IOR in survivors. Others however could not confirm an increased incident of NND or worsened after IOR in their study groups. [2, 53, 56] These discrepancies may be explained by the fact that outcome measurement by GOS is not a very sensitive improvement. Other factors like SAH, vasospasm may also play a role. However it is uniformly accepted that a true deterioration was observed in patients with IOR during the pre exposure phase.

Leipzig[2] in his extensive review has attempted to correlate outcome with the severity of intraoperative rupture. He observed that of those experiencing a major IOR, one-half sustained a stroke before discharge, and one-third died. The rates of mortality (12.5%) and stroke (28.1%) were substantially less for patients experiencing a moderate IOR. In patients with minor IOR, half recovered without serious deficit. Of note, more than 50% of all patients with IOR in this series experienced a good outcome (without significant deficits).

Our findings are similar to those of the majority in that IOR does not necessarily result in poor outcome. In the present series good outcome at time of discharge (Table 24) was observed in 84% (GOS 1 & 2). At one year follow up, only sixty-three patients were available of which 92% were doing well and had a GOS of one or two (Table twenty five).

Factors predisposing to Intra operative rupture-

We conclude that predicting the risk of intraoperative rupture in patients undergoing surgery for anterior communicating artery aneurysms is extremely difficult. Of the variables analyzed age, sex, timing of surgery, previous history of SAH had no predictive value as factors predisposing to intra operative rupture. Preoperative hydrocephalus definitely predisposes to intraoperative rupture but the predictive value was found to be statistically weak.

Factors predicting outcome following intraoperative aneurysm rupture-

Once intraoperative rupture occurs overall outcome depends on several variables. Factors adversely affecting outcome in anterior communicating artery aneurysm patients having intraoperative rupture include

- Early rupture (during craniotomy or dural opening)
- Size of aneurysm greater than 10 mm
- Anterosuperiorly and inferiorly projecting aneurysms
- Prolonged temporary clip more than 10 minutes
- Type I circulation
- Preoperative vasospasm,

Factors, which do not adversely influence overall outcome following intraoperative rupture of an anterior communicating artery aneurysm include

- Age
- Sex
- Preoperative hydrocephalus
- Timing of surgery
- Preoperative WFNS grade
- Multiple aneurysms
- Rupture during dissection or clipping
- Temporary clip application less than 10 min.

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