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CONTRALATERAL APPROACH TO ANTERIOR CIRCULATION ANEURYSMS

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To my family



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List of Original Publications

I.

Andrade-Barazarte H, Kivelev J, Goehre F, Jahromi BR, Hijazy F, Moliz N, Gauthier A, Kivisaari R, Jääskeläinen JE, Lehto H, Hernesniemi JA. Contralateral approach to internal carotid artery ophthalmic segment aneurysms: angiographic analysis and surgical results for 30 patients. *Neurosurgery*. 2015 Jul 1;77(1):104-12.

II.

Andrade-Barazarte H, Kivelev J, Goehre F, Jahromi BR, Noda K, Ibrahim TF, Kivisaari R, Lehto H, Niemela M, Jääskeläinen JE, Hernesniemi JA. Contralateral Approach to Bilateral Middle Cerebral Artery Aneurysms: Comparative Study, Angiographic Analysis, and Surgical Results. *Neurosurgery*. 2015 Dec 1;76(6):916-26.

III.

Andrade-Barazarte H, Luostarinen T, Goehre F, Kivelev J, Jahromi BR, Ludtka C, Lehto H, Raj R, Ibrahim TF, Niemela M, Jääskeläinen JE. Transient Cardiac Arrest Induced by Adenosine: A Tool for Contralateral Clipping of Internal Carotid Artery-Ophthalmic Segment Aneurysms. *World neurosurgery*. 2015 Dec 31;84(6):1933-40.

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Abbreviations

A1,	Anterior cerebral artery proximal segment
ACP,	Anterior clinoidal process;
BIAs,	Bilateral intracranial aneurysms;
bMCA,	Bilateral middle cerebral artery
CSF,	Cerebrospinal fluid;
CT,	Computed tomography;
CTA,	Computed tomographic angiography;
DSA,	Digital subtraction angiography
ECG,	Electrocardiogram
HH,	Hunt and Hess scale
IAs,	Intracranial aneurysms;
ICA,	Internal carotid artery;
ICAbif,	Internal carotid artery bifurcation
ICAbifs,	Internal carotid artery bifurcations
ICA-opht,	Internal carotid artery ophthalmic segment;
LSO,	Lateral supraorbital approach
MCA,	Middle cerebral artery;
MIAs,	Multiple intracranial aneurysms;
M1,	Middle cerebral artery proximal segment
MRA,	Magnetic resonance angiography;
MRI,	Magnetic resonance imaging;
mRS,	Modified Rankin Scale;
OphtA,	Ophthalmic artery;
PcoA,	Posterior communicating artery;
SAH,	Subarachnoid hemorrhage;

Abstract

Objective

Multiple intracranial aneurysms are frequent, with an incidence of 15-40% among intracranial aneurysms carriers. Of these carriers, 20-40% have bilateral intracranial aneurysms. The rupture risk is higher for patients with multiple intracranial aneurysms. For those patients, several treatment options are available (microsurgery comprising a unilateral-contralateral approach, bilateral craniotomies in one-stage or two stages surgery, and endovascular methods) varying from institution's resources and surgeon's experience. The present study focuses and analyses the angiographic characteristics, specific parameters, and surgical results of the unilateral-contralateral approach for ICA-opht segment and MCA aneurysms. In addition, it describes and analyses the proximal vascular control by transient cardiac arrest induced by adenosine during the contralateral clipping of ICA-opht segment aneurysms.

Patients and Methods

We retrospectively reviewed 68 patients with ICA-opht segment and bMCA aneurysms treated through a contralateral approach at the department of neurosurgery of the University of Helsinki, between January 1998 and December 2013. A detailed analyses of the aneurysms characteristics and constrains of

the contralateral surgical corridor was performed. A further subgroup analysis of 8 patients harboring ICA-opht segment aneurysms approached through a contralateral craniotomy and requiring intravenous adenosine administration to induce transient cardiac arrest during microsurgical clipping was performed as well.

Results

ICA-opht segment aneurysms: All the 30 ICA-opht aneurysms were small (less than 7 mm), unruptured, saccular, and had no wall irregularities, calcifications or secondary pouches. Microsurgical clipping of these aneurysms was possible when the prechiasmatic distance had a median of 5.7 mm (range 3.4-8.7 mm) and the interoptic distance a median of 10.5 mm (range, 7.6-15.9). The most frequent aneurysm dome projection was superomedial (77%). Of the patients with ICA-opht segment aneurysms approached through a contralateral craniotomy, 93% had good postoperative outcome at 3-month follow-up.

bMCA aneurysms: The contralateral approach for bMCA aneurysms was possible in 38 patients. All the 38 contralaterally approached MCA aneurysms were unruptured and had saccular shape (except one with bilobular shape). The ma-

majority (97%) of contralateral aneurysms were small to medium in size. The median length of the contralateral A1 was 13.2 mm (range: 6-19.8 mm), and the median length of the contralateral M1 was 14.2 mm (range: 4.6-21 mm). Of the patients with unruptured bMCA aneurysms treated through a contralateral approach, 24 (86%) patients had good outcome and 4 (14%) had poor outcome at 3-month follow-up, 1 patient was lost to follow-up. There were 9 patients harboring bMCA aneurysm presented with SAH due to a ruptured ipsilateral aneurysm. Of these patients, 7 (78%) had good outcomes, and 2 (22%) had poor outcomes at 3 months. Olfactory disturbances were present in 21% of cases treated through a contralateral approach.

Transient cardiac arrest induced by adenosine during contralateral clipping of ICA-opht aneurysms: 8 patients received intravenous bolus of adenosine to induce transient cardiac arrest during clipping. Of the total patients, 5 received single bolus of adenosine, and 3 patients received multiple doses. The median single dose of adenosine was 22.5 mg (range, 5-50 mg). The asystole time range between 20-40 seconds after adenosine administration. All the 8 patients showed good surgical outcomes at 3-month and 1-year follow-up, and showed no procedure-related complications.

Conclusion

The contralateral approach remains as a feasible option for microsurgical treatment of ICA-opht segment aneurysms, and bMCA aneurysms. Its feasibility depends on general parameters related to the aneurysm itself (shape, morphology,

size, status and projection), and specific parameters that varies according to the vascular segment to be treated (prechiasmatic and interoptic distances, length of A1 and M1). Transient cardiac arrest induced adenosine represents a useful tool to obtain proximal vascular control while performing a contralateral approach for ICA-opht segment aneurysms in selected patients.

1. Introduction

Microsurgical approaches for the treatment of anterior circulation aneurysms have undergone important developments in the last centuries^{132, 146, 212}. In 1855, Sir Victor Horsley was the first to treat a brain aneurysm by carotid ligation. In 1937, Prof. Walter Dandy was the first one to apply “the clipping technique” to occlude the neck of an internal carotid artery aneurysm using a V-shape silver clip around the aneurysm neck.³³ Since the beginning of the microsurgical era, surgical techniques, instruments and treatment modalities have been continuously evolving with a current tendency for less invasive procedures.

Multiple intracranial aneurysms (MIAs) are common, having a documented incidence of 15-40% among intracranial aneurysms (IAs) carriers.^{24, 165, 179} Of these carriers, 20-40% have bilateral intracranial aneurysms (BIAs).^{24, 102} MIAs carriers have a higher rupture risk.¹ The current tendency is to treat the maximal possible number of lesions during the first attempt using the most adequate technique according to the institution and surgeon’s experience (endovascular or surgical treatment).

Different surgical modalities have been proposed to treat BIAs (unilateral-contralateral approaches, bilateral craniotomies via one stage or two stage surgeries). The contralateral approach offer potentials advantages over bilateral craniotomies, as it spares an additional craniotomy, and reduces operative times and surgical costs to the patient and to the institution.

In this report, we focused on the unilateral or contralateral approach to treat BIAs or single aneurysms located on the contralateral side of the craniotomy.

While there are several reports that describe the technique of the contralateral approach^{40, 41, 92, 130, 135, 148, 180, 204}, there is still lack of studies that outline angiographic characteristics,

patient selection criteria, and surgical results of treatment of the anterior circulation aneurysms through a contralateral approach. In addition, the surgical technique of previous reports has focused on utilizing the orbitozygomatic or pterional approaches.^{40, 41, 84, 92, 135, 166, 180}

In present report, we focused on the application of unilateral or contralateral approach to treat BIAs or single aneurysms located on the contralateral side to the craniotomy. Furthermore, all the contralateral clipping and exposure were performed through a minimally invasive lateral supraorbital approach (LSO).⁸⁰ Our purpose was to establish anatomical and radiological parameters to determine the feasibility of the use of the contralateral approach for treatment of intracranial aneurysms located on the internal carotid artery (ICA), ophthalmic segment (ICA-opht), and the middle cerebral artery (MCA). More specifically, we described angiographic characteristics of the aneurysms located on the above mentioned vascular segments, their radiological measurements, distances of the contralateral surgical corridor, techniques for proximal vascular control, as well as surgical outcomes and complications of using a contralateral LSO approach for treatment of anterior circulation aneurysms.

2. Review of the literature

2.1 Intracranial Aneurysms and subarachnoid hemorrhage

2.1.1 Epidemiology of IAs

IAs are acquired lesions with a prevalence of 1-3% in the general population.^{22, 99, 184} IAs are responsible of about 80-85% of non-traumatic subarachnoid hemorrhages.¹⁰⁴ MIAs are common, with an incidence of 15-40% among aneurysms carriers.^{24, 91, 96, 102} Of these carriers, 20-40% have bilateral intracranial aneurysms comprising both brain hemispheres.^{24, 91, 96, 102, 149}

2.1.2 IAs formation

IAs are generally accepted to be acquired lesions. However, its formation mechanism is still controversial. Current theory for aneurysm formation acknowledges the presence of underlying endothelial dysfunction that leads to pathological remodeling with degenerative changes of vascular walls.¹⁰⁵ Additional mechanisms for aneurysm formation include direct trauma, infection, hemodynamic changes, and inflammation.^{14, 19, 60, 62, 94}

2.1.3 Genetics

General genome-wide linkage studies have identified several loci on chromosomes 1p34.3-p36.13, 7q11, 19q13.3, and Xp22 that may predispose to IAs formation.^{22, 54, 63, 112, 219} Furthermore, several inherited disorders are associat-

ed with a higher incidence of IAs. These conditions include autosomal dominant polycystic kidney disease, neurofibromatosis type I, Marfan syndrome, and Ehlers-Danlos syndrome type II and IV.^{143, 185, 190, 191}

2.1.4 Histology

IA wall lacks elastic lamina and is subject to different degrees of degenerative changes and inflammatory reactions degrading the extracellular matrix, the elastic lamina of the vascular wall, and finally affecting the integrity of the vessel lumen.^{59, 115, 116} Frösen et al identified four histological wall types of IAs: type A, endothelialized wall with linearly organized smooth muscle cells (SMC); type B, thickened wall with disorganized SMC; type C, hypocellular wall; and type D, extremely thin thrombosis-lined hypocellular wall.^{59, 61, 62} The wall of an unruptured aneurysm displays myointimal hyperplasia and organized thrombi. On the other hand, ruptured aneurysm wall is degenerated and decellularized with evidence of ongoing inflammatory reaction, lipid accumulation and oxidative stress.^{59, 115, 116}

2.1.5 Morphology of IAs

Morphologically IAs are classified into two categories: the classical saccu-

lar aneurysms, and the fusiform (non-saccular) aneurysms. Saccular aneurysms represents up to 97% of IA, and are associated to the branching points of the parent vessel.^{52, 115} Fusiform aneurysms are spindle-shape dilatations compromising a complete segment of an artery and lack an identifiable neck. The literature contains multiple variations of aneurysm nomenclature that reflect the pathophysiological mechanisms of aneurysm formation, such as dissecting aneurysms, serpentine aneurysms, atherosclerotic aneurysms, mycotic or infectious aneurysms, and traumatic aneurysms.^{115, 186}

2.1.6 Risk Factors

Risk factors for intracranial aneurysm growth include age older than 50 years, female gender, smoking history and non-saccular shape.^{18, 97, 99} Risk factors for aneurysm rupture are female gender, current smoking status, location and size of the aneurysm, hypertension, and patient age.^{4, 91, 97, 98, 110, 111} Aneurysm growth during follow-up is associated with a rupture rate of 3.1% per year.¹⁸

2.1.7 Aneurysmal subarachnoid hemorrhage

Subarachnoid hemorrhage (SAH) secondary to aneurysmal rupture is a neurological emergency resulting in extravasation of blood into the subarachnoid space. The incidence of aneurysmal SAH in most populations varies from 6-10 cases per 100.000 person year.⁷⁰ Japan, Northern Sweden and Finland according to previous studies carry a higher rupture rate.^{1, 70, 110 111}



Figure 1. Axial CT of a ruptured AcoA aneurysm and unruptured BMCA aneurysms.

2.1.8 Diagnostics

Noncontrast computed tomography (CT) remains the cornerstone imaging study for SAH diagnosis. The sensitivity of CT in the first three days of a SAH onset is close to 100%.^{3, 12} After 5-7 days of the SAH onset and in the presence of a negative noncontrast CT, a lumbar puncture is recommended to clarify the diagnosis of SAH.¹² For aneurysm detection, digital subtraction angiography (DSA) continues to be the gold standard technique. However, with the advancing technologies and less invasive procedures computed tomography angiography (CTA) has gained more territory on the detection of these lesions and surgical planning.^{23, 134, 155} Compared to DSA, CTA is less invasive, cheaper and faster to perform. In addition, it allows better visualization of bony landmarks in relationship with blood vessels. Finally, 3-dimensional CTA reconstructions images facilitate the surgeon to mimic the surgical field preoperatively.²³

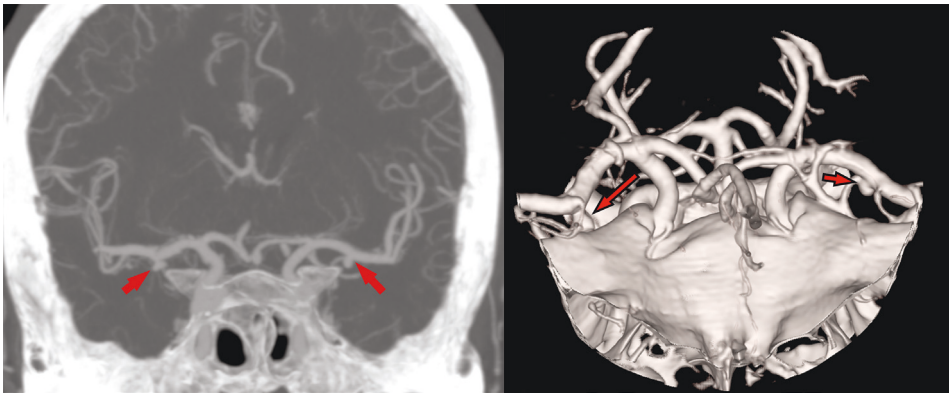


Figure 2. Coronal CTA and 3D CTA of bMCA aneurysms

2.1.9 SAH classification

Several SAH classifications have been used to describe the clinical condition of the patient and correlate it with the hemorrhagic distribution on the radiological findings. The most frequently used clinical scales include the Hunt and Hess scale, and the World Federation of Neurological surgeons scale.^{2, 88} Among the radiological scales, the modified Fisher scale is used to predict the risk of developing cerebral vasospasm.⁵¹ In combination, these clinical and radiological scales of SAH are useful to provide an estimate on patients' outcome.^{25, 128}

2.1.10 SAH complications

Aneurysm rebleeding represents the first cause of morbidity and mortality after SAH. In 12% of the cases rebleeding occurs within the first 24 hours. Subsequently, the rate of rebleeding decreases to 1-2% per day for the following two weeks. After the first month, the risk decreases but remains up to 3% per year.¹⁹⁹

Cerebral vasospasm after SAH is the leading preventable cause of disability and mortality in patients who experienced an intracranial aneurysm rupture.^{90, 103} Ce-

rebral angiographic spasm may be present radiologically in up to 50-70% of SAH patients^{32, 47}. However, its clinical manifestation may occur in up to 50% of SAH patients.^{7, 43, 46, 47} Cerebral vasospasm can be diagnosed by transcranial Doppler ultrasound, CTA, MRA, DSA or CT perfusion.¹²⁶ Furthermore, development of delayed cerebral ischemia (DCI) and cerebral vasospasm are associated with poor outcomes in SAH patients.^{43, 46, 47, 103} Other neurological complications of aneurysmal SAH include hydrocephalus and seizures.^{21, 74, 89, 127, 171} Additionally, non-neurological complications comprised of cardiac arrhythmias, hypernatremia, pulmonary edema, renal dysfunction, myocardial infarction, and hepatic dysfunction.^{42, 55, 72, 160, 200, 210}

2.1.11 Treatment

The main goals of treatment of acute aneurysmal SAH are, first, to secure the aneurysm to prevent its re-rupture, and second, to manage the complications of SAH.^{144, 202, 208} Clinical cerebral vasospasm can be actively managed using medical therapy or endovascular options. Nimodipine has shown to reduce the incidence of ischemic complications associated with vasospasm and to improve neurological outcomes.^{6, 16, 20, 31, 44, 198} Additional therapies include intra-arterial verapamil infusions and mechanical angioplasty of narrowed arterial segment.^{69, 87, 109, 125, 133, 139, 161, 162, 200, 53, 133, 153} Classically, the widely used “Triple H therapy” comprised of hypervolemia, hypertension and hemodilution represents the main medical treatment of vasospasm, after occlusion of the ruptured aneurysm.^{114, 120} Non-neurological complications and associated co-morbidities should be managed by a multidisciplinary team.^{68, 72, 172}

2.2 History of Craniotomies and Evolution of Surgical Approaches

During the past centuries surgical procedures to treat intracranial lesions have constantly evolved due to our better understanding of brain anatomy, improvements in anesthesia, antisepsis, hemostasis, lesion localization and radiological images.^{212, 146} The evolution of the first frontotemporal approach to keyhole craniotomies and endovascular procedures follows a marked tendency of minimally invasiveness with the main purpose to improve results, outcomes, occlusion rate and cosmesis for the patient.^{80, 93, 146, 212, 217, 218}

2.2.1 Frontotemporal approach

George Heuer (1882-1950) developed the frontotemporal approach as a means of getting better access to hypophyseal tumors and as a modification of previous work of Sir Victor Alexander Horsley, Frank T. Paul, and Fedor Victor Krause among others.⁸² However, it was Walter Dandy who initially described this approach in 1917 due to the insistence of William Halsted since Heuer was in France during the World War I.³⁴ The initial approach consisted in a cut in the form of the Greek Omega sign, a very large osteoplastic craniotomy involving the supra-orbital margin and with base parallel to the zygoma.⁸² This approach would allow access to the optic chiasm, facilitate dislocation (relaxation) of the brain by CSF drainage, and retraction of the frontal and temporal lobes.^{34, 82} In 1937, Walter Dandy was the first to clip an intracranial aneurysm through the frontotemporal approach.³³

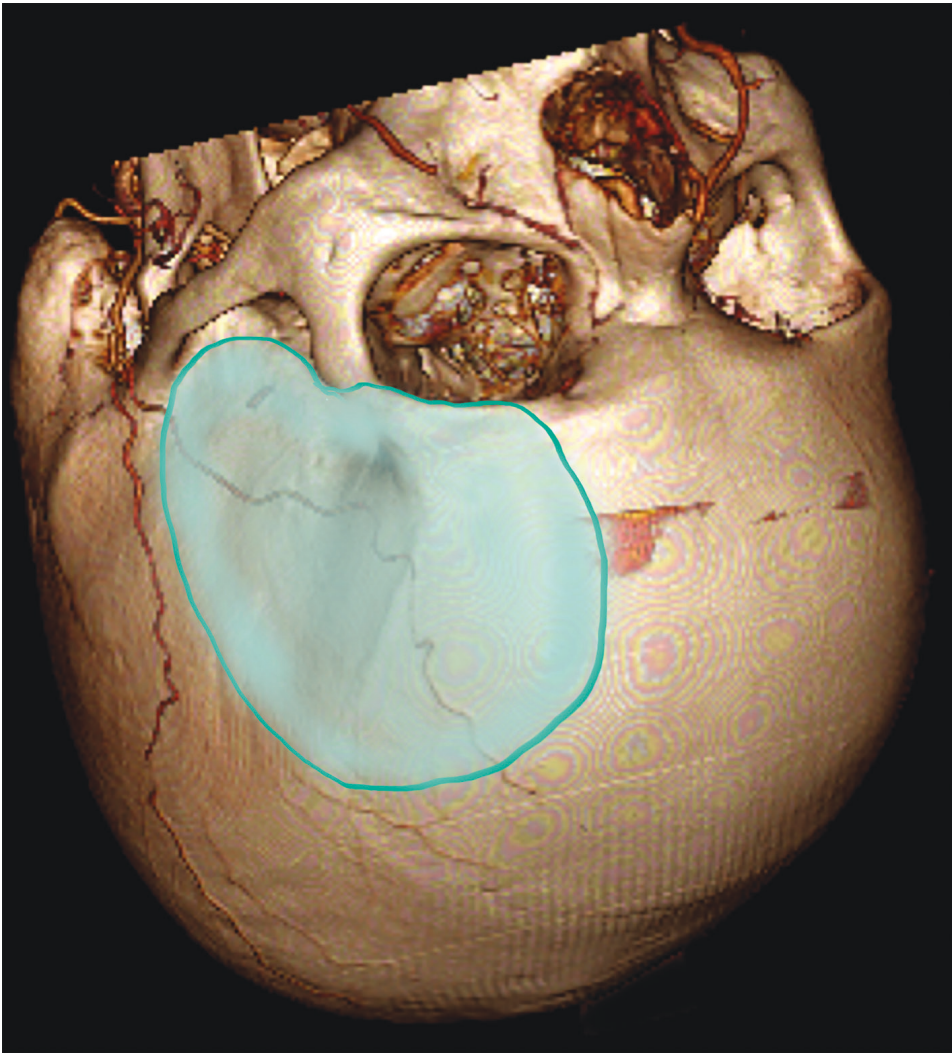


Figure 3. 3D skull image demonstrating planned craniotomy of a left frontotemporal approach.

2.2.2 Pterional approach

Gazi Yaşargil who is considered the father of the modern microsurgery, played an important role in the improvement of the previously described frontotemporal approach by incorporating the use of microscope in neurosurgery.^{217, 218} The operating microscope offered better illumination and magnification allowing the surgeon to improve their technique and achieve better precision.¹¹³

The pterional approach as described by Yaşargil et al in 1967^{113, 216} requires a curvilinear skin incision starting 1 cm anterior to the tragus and extending perpendicularly to the zygomatic arch until the midline behind the hairline. Further advantages of this approach over the previous frontotemporal craniotomy include the development of interfascial dissection of temporalis muscle to avoid damage to the fron-

totemporal branch of the facial nerve, while maximizing temporalis muscle retraction and subsequent visibility along the sphenoid ridge, better cosmetic results, and smaller craniotomy size with emphasis on the skull base to limit brain retraction. The pterional approach has been widely accepted as the “work-horse” of modern microsurgery.^{76, 77, 130, 140, 145, 164, 188, 217, 220}

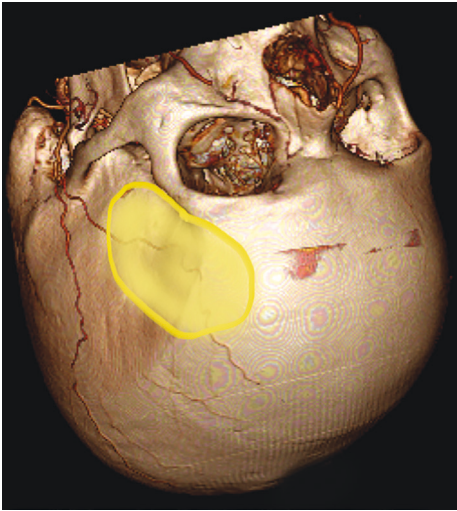


Figure 4. 3D skull image demonstrating planned craniotomy of a left pterional approach.



Figure 5. Left curvilinear skin incision for a pterional approach.

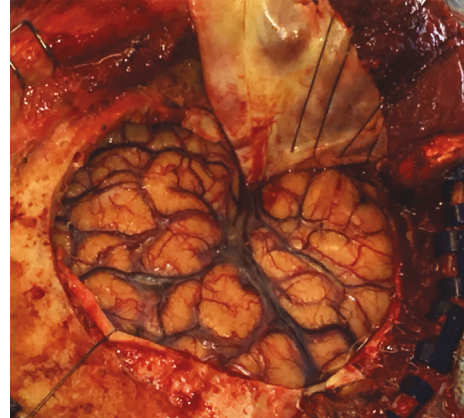


Figure 6. Right pterional craniotomy

2.2.3 Lateral supraorbital approach (LSO).

The lateral supraorbital approach (LSO) described by Juha Hernesniemi et al⁸⁰ in 2005, emerged as a less invasive and faster modification of the previous pterional approach. The LSO employs a shorter skin incision, induces less trauma to the temporalis muscle (only the superior aspect is detached), creates a one-layer flap (myocutaneous flap) and a smaller more frontal craniotomy with the Sylvian fissure at the inferior limit. The key points marking the extent of the LSO craniotomy are the zygomatic process of the frontal bone and the projection of the Sylvian fissure, resulting in a craniotomy of approximately 4 cm in diameter. Through this approach all intradural work is performed subfrontally. Juha Hernesniemi has used the LSO approach to access pathologies involving the anterior cranial fossa, the majority of anterior circulation aneurysms (except those distal to the A2 segment), and some posterior circulation aneurysms including basilar tip aneurysms (except high positioned basilar tip aneurysms), posterior cerebellar artery aneurysms and superior cerebellar artery aneurysms.^{35-37, 67, 79, 121-124, 181-183}

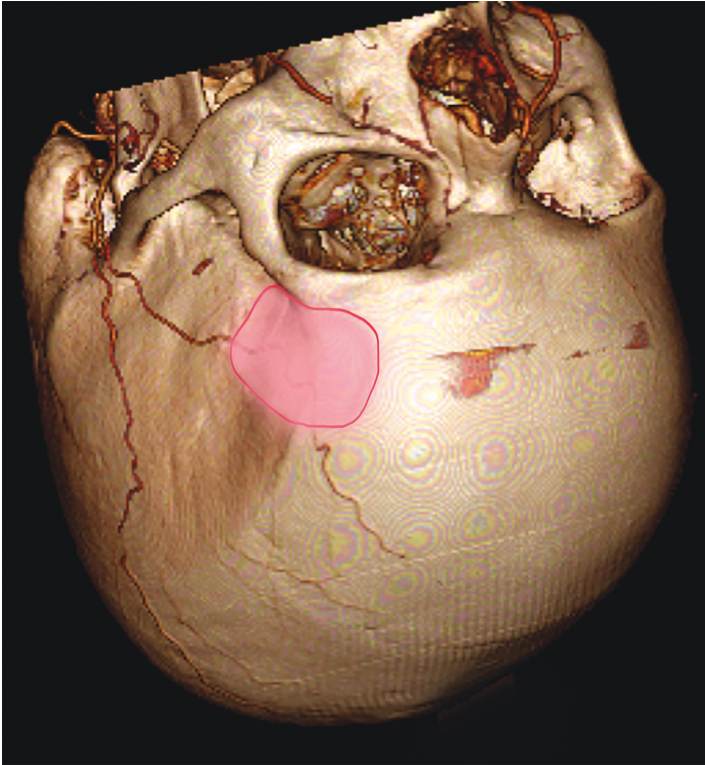


Figure 7. 3D Skull image demonstrating planned craniotomy of a left lateral supraorbital approach.



Figure 8. Right curvilinear skin incision for a lateral supraorbital approach.

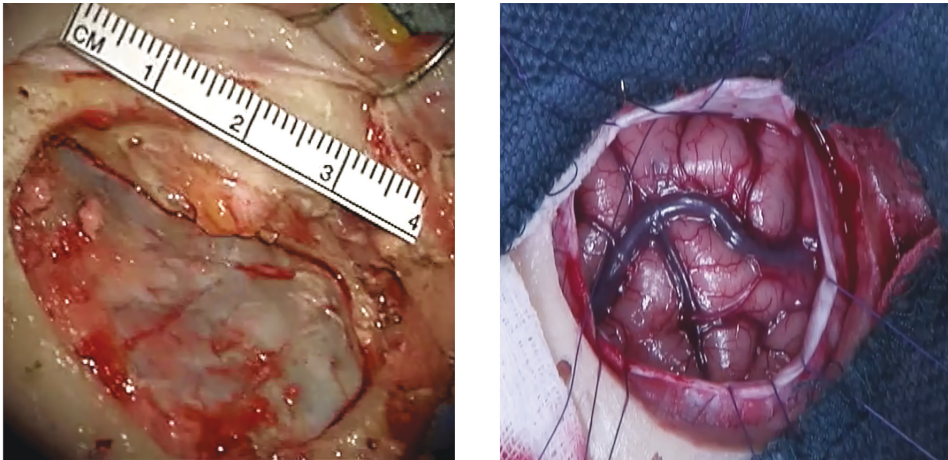


Figure 9. Craniotomy and dural opening of a right lateral supraorbital approach.

2.2.4 Keyhole supraorbital approach (eyebrow approach)

Popularized by Axel Perneczky (1945-2009), the keyhole supraorbital approach consists of a subfrontal approach performed through an eyebrow incision.²⁰⁶ Key aspects of this approach include proper head and bed positioning, as well as the use of the microscope or endoscope for better visualization and illumination at the depth. The skin incision is placed lateral to the supraorbital notch to avoid injury of the supraorbital nerve. The dissection continues laterally to avoid damage of the frontalis branch of the facial nerve.^{15, 30, 81, 147, 203} Multiple hooks are placed around the skin incision to improve the surgical exposure and a craniotomy of about 1.5 – 2 cm in width is performed to allow manipulation of microsurgical instruments. The literature counts with around 2500 cases performed through this approach.¹⁴⁷ According to Perneczky, through the supraorbital keyhole the “optical field widened with increasing distance from the keyhole, and contralateral structures could be visualized well”^{174, 206}

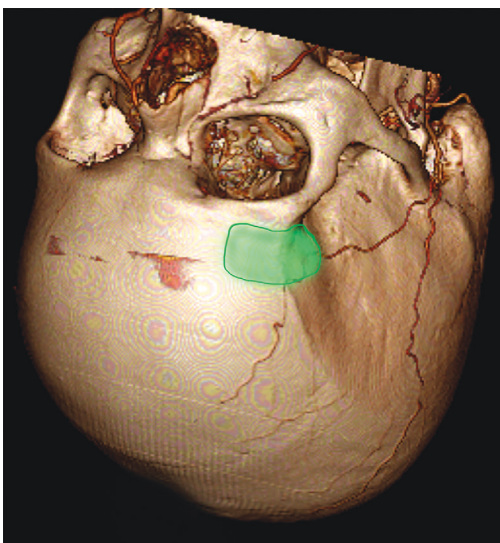


Figure 10. 3D skull image demonstrating planned craniotomy of a right supraorbital keyhole approach.



Figure 11. Right eyebrow skin incision for a supraorbital keyhole approach.

2.2.5 Mini-pterional approach

Described by Nathal et al and later refined but Figueredo et al^{48, 141} this approach represents a keyhole craniotomy focused on the sphenoid ridge. This approach resembles a similar opening to the pterional approach but with a smaller craniotomy with reduction of frontal and temporal bony work. The short skin incision and minimal dissection of the temporalis muscle are characteristics that are shared with the LSO approach. The mini-pterional approach provides a craniotomy of about 2 cm in diameter, and it has been used to access lesions on the inferior frontal and superior temporal gyri, anterior ascending ramus of the Sylvian fissure, ICA and MCA aneurysms.^{48, 141, 212}



Figure 12. Left side skin incision for a mini-pterional approach

	FRONTOTEMPORAL	PTERIONAL	LATERAL SUPRAORBITAL	EYE-BROW SUPRAORBITAL	MINI-PTERIONAL
Skin incision	Large form of the Greek Omega sign	Behind the hairline, starting at the root of the zygoma passing the midline	Behind the hairline, beginning 3 cm. above the zygoma to the midpupillary line	Eye-brow incision placed lateral to the supraorbital notch	Behind hairline, beginning 2 cm. above the zygoma to the midpupillary line
Temporalis muscle dissection	Osteoplastic craniotomy	Interfascial dissection, temporalis muscle completely dissected	Myocutaneous flap (only the superior and anterior aspect of temporalis muscle dissected)	Interfascial, minimal anterior temporalis muscles dissected	Interfascial or myocutaneous, temporalis muscle incised superoanteriorly
Location of craniotomy	Frontal, pterion, squamos temporal bone, supraorbital rim and zygoma	Frontal, pterion, squamous temporal bone	Frontal, between zygomatic process of the frontal bone, greater sphenoid wing and superior temporal line	Between supraorbital notch and frontozygomatic suture	Superior temporal line, pterion and squamous temporal
Size of craniotomy	10-12 cm	6 x 6 cm	4 x 4 cm	2.5 x 2 cm	3 x 3 cm
Sphenoid drilling	Not described	To superior orbital fissure	Not required	Not required	To superior orbital fissure
Brain (cortical exposure)	Frontal, temporal lobes and Sylvian fissure	Frontal, temporal lobes and Sylvian fissure	Inferior frontal gyrus, edge of the Sylvian fissure	Frontal pole and orbital gyrus	Inferior frontal, superior temporal gyrus and Sylvian fissure
Sylvian fissure opening	Yes	Yes	Optional	Optional	Yes

Table 1. Comparisons of surgical approaches.

2.2.6 Endoscope-assisted approaches

Fischer and Mustafa reported the first endoscope-assisted aneurysm surgery in 1994.⁵⁰ Since then, multiple reports have described the advantages and complications of this procedure.^{101, 108, 163, 173} In endoscope-assisted approaches, the majority of dissection is performed under the operating microscope regardless of the type of craniotomy used. During aneurysm surgery, the endoscope-assisted approach has 3 applications: a) inspection before clipping, b) clipping under endoscopic vision, c) post clipping revision of hidden corners and perforators. Perneczky and Fries popularized endoscopic-assisted approach through the supraorbital keyhole craniotomy.^{56, 101, 108, 157, 158, 163, 173}

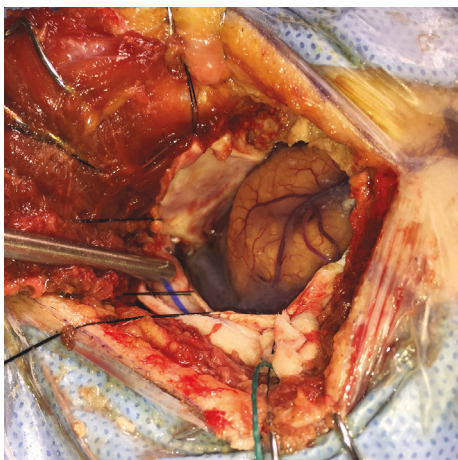


Figure 13. Left side mini-pterional approach for endoscope-assisted aneurysm clipping

2.2.7 Purely endoscopic approach

As technology continues to advance, microsurgical and endoscopic instruments are subject to new developments and improvements demonstrating the need of smaller and less invasive approaches. Purely endoscopic approach for aneurysm surgery is at the initial stage; being performed either through a small craniotomy as the ones previously described or through endoscopic ports. To the date only small case series of purely endoscopic approaches have been published, Perneczky et al reported one of the largest series with 7 aneurysms clipped purely through an endoscopic approach.^{49, 57, 157} Advantages of this approach include the lack of need for switching between microscope and endoscope, use of endonasal or smaller mini-craniotomies, and less brain retraction.^{49, 57, 157}

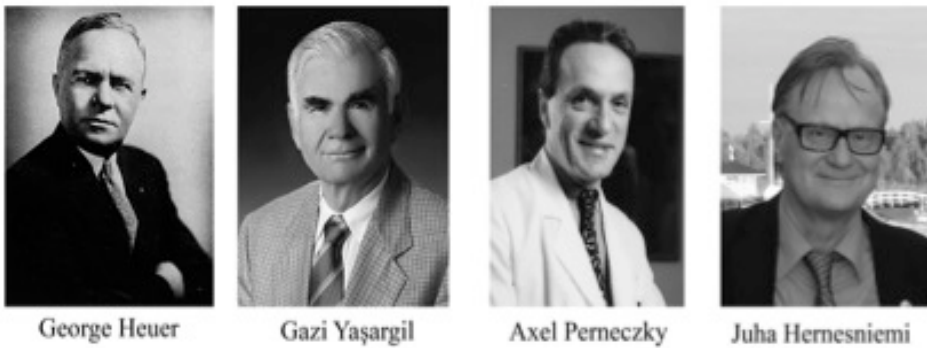


Figure 14. Surgeons that influenced surgical approaches evolution



Figure 15. Some cerebrovascular surgeons that fomented the contralateral approach for IAs

2.3 Multiple intracranial aneurysms

MIAs are common and have a documented incidence between 7-35%.^{28, 102, 179} BIAs represents 20-40% of these MIAs carriers.^{91, 96, 102, 149, 165, 179} The risk of aneurysmal rupture is higher when MIAs are found in the presence of SAH.¹ The main goal in this context is to secure the ruptured aneurysm and to treat as many of the remaining lesions as possible without affecting the outcome of the patient. If only the ruptured aneurysm is treated, there exists a small theoretical risk of bleeding from one of the incidental aneurysms at the time of aggressive management of vasospasm and other complications related to the SAH.^{75, 86, 209}

Several treatment strategies have been reported of MIAs and BIAs management that vary according to the institution's resources and surgeon's experience.^{1, 26, 28, 40, 41, 83, 85, 131, 135, 136, 178, 189, 194}

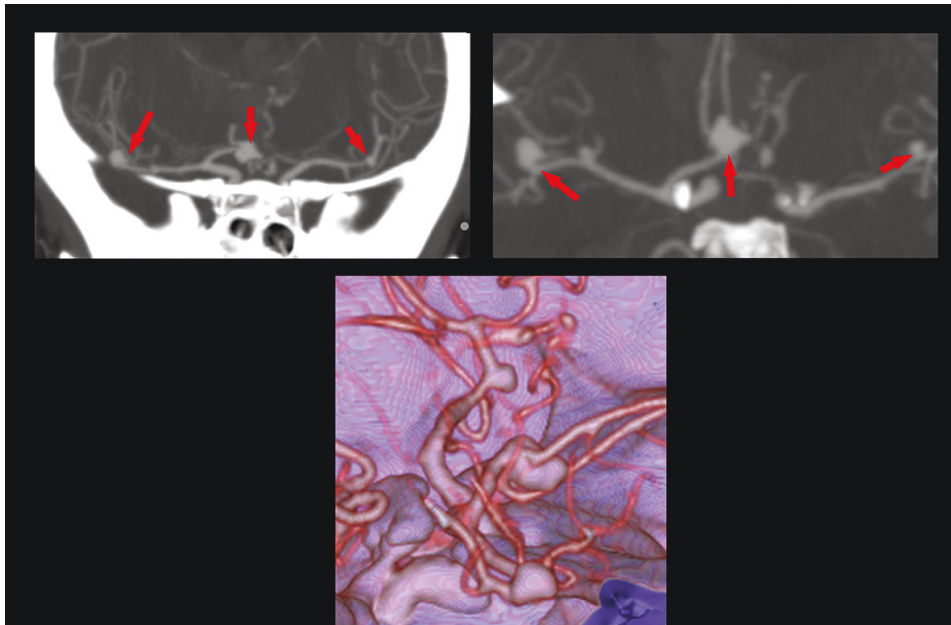


Figure 16. CTA coronal, axial and 3D reconstruction demonstrating MIAs

2.3.1 Microsurgical Management

2.3.1.1 Unilateral approach (contralateral approach)

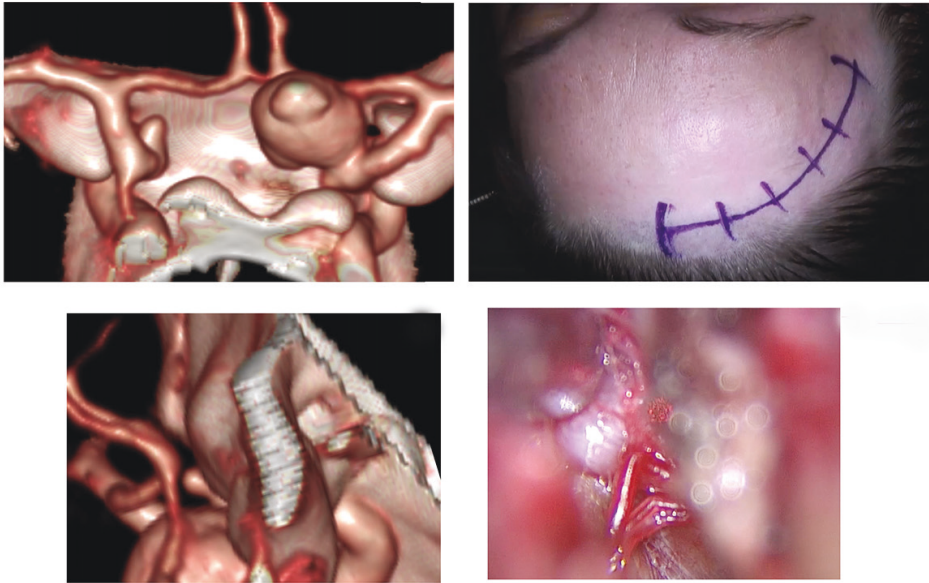
The unilateral and contralateral approach consist in performing a craniotomy on one side (pterional, orbitozygomatic, LSO, supraorbital keyhole) to first treat the aneurysm located on the ipsilateral side and then follow the natural pathways of the arachnoid planes and cisterns to identify and secure the contralateral aneurysm without performing an additional craniotomy. Nakao et al performed the first reported contralateral clipping in 1981.¹⁴⁰ As more microsurgical experience is gained through less invasive approaches, in addition to improvements in imaging technology resulting in our better appreciation of the three-dimensional anatomical configuration of the aneurysm, more surgeons begin to use the contralateral approach in selected patients.^{26-28, 41, 58, 83, 84, 135, 137, 140, 148, 166, 180, 189, 192, 201, 204, 213}

a) 3D CTA showing bilateral ICA-opht segment aneurysms, b) Right curvilinear skin incision for a LSO, c) 3D CTA mimicking the surgical trajectory for a contralateral approach of a left ICA-opht segment aneurysm, d) Intraoperative picture of the left ICA-opht segment aneurysm.

2.3.1.2 Bilateral Craniotomies (one-stage surgery or two-stage surgery)

As previously mentioned, management of multiple and bilateral IAs remains con-

Figure 17. Bilateral ophthalmic segment aneurysms treated through a right LSO.



troverisal. It has been generally accepted that in patients presenting with acute SAH and harboring bilateral aneurysms, the first treatment should be focused on the ruptured aneurysm through an ipsilateral craniotomy and therefore let the remaining contralateral unruptured aneurysm for a second craniotomy, which can be performed at the time of securing the rupture source (one-stage surgery), or in a second delayed surgery once the patient has completely recovered from the initial bleed.^{92, 131, 136}

2.3.2 Endovascular treatment

Multiple factors interfere with the decision process while choosing endovascular treatment for MIAs over surgical management. Clinical condition of the patient, presence of comorbidities, presence of ICH and IVH, location of the aneurysm, presentation or status of the aneurysm (ruptured vs. unruptured) all play an important role on the therapeutic management. The endovascular treatment is based on the same

principle of securing the ruptured aneurysm first when accessible followed by treating the remaining unruptured aneurysms in the same session or at a later time.^{107, 193, 196, 207}

2.4 Microsurgical anatomy of anterior circulation segments reached through the contralateral approach

2.4.1 Ophthalmic segment: extending from the origin of the OphtA to the origin of the PCoA. Includes the OphtA and several small superior hypophyseal arteries arising from the medial or inferomedial wall of ICA. Access to this segment is achieved through the inter-optic space and the chiasmatic cistern.^{65, 177} From the contralateral side of view, in majority of cases, ophthalmic artery arises from the medial or superomedial aspect of the ICA. Thus, in the presence of ophthalmic segment aneurysms that are superiorly or medially projected, the aneurysm dome or neck is found in line with the surgical trajectory and is well visualized. In some circumstances,

however, the dome is positioned under the contralateral optic nerve requiring some degree of dome mobilization to occlude the aneurysm^{65, 177, 214}.

2.4.2 Communicating segment: extending from the origin of the PCoA to the origin of the AChA; in this segment PCoA takes its origin from the inferolateral wall of the ICA^{40, 65, 177, 214}.

2.4.3 Choroidal segment: extending from the origin of the AChA at the inferolateral aspect of ICA to its bifurcation. These two particular segments are difficult to expose through the contralateral approach due to the usual lateral or posterior projection of the aneurysms in this location. Identification of the origins of the PCoA or AChA is difficult as they are partially hidden by the ICA and the contralateral optic nerve or chiasm.^{40, 65, 177, 214}

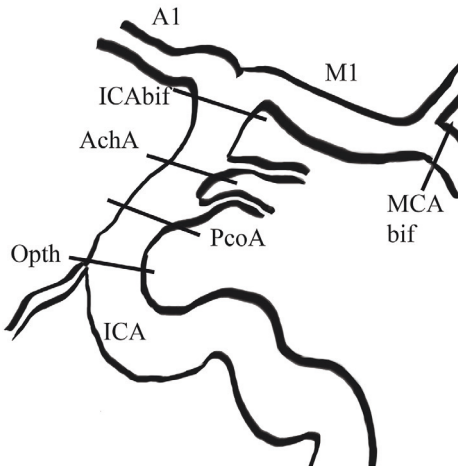


Figure 18. Schematic drawing demonstrating vascular segments reached through a contralateral approach

2.4.4 ICA bifurcation segment: the terminal segment of the ICA. The ICA bifurcates at the superoposterior end of the carotid cistern, lateral to the optic chiasm

and below the anterior perforating substance into 2 terminal branches, the M1 and the A1. The carotid cistern contains the ICA bifurcation and the proximal portions of the A1 and M1 segments. The^{65, 177}

2.4.5 A1 segment: located between the ICA bifurcation and the junction of the A1 and A2 segments at the ACoA complex.

2.4.6 M1 segment: extending from the ICA bifurcation to the MCA bifurcation.

The M1 segment begins at the carotid bifurcation and runs laterally towards the Sylvian fissure, below the anterior perforated substance and in the depths of the Sylvian vallicula.^{40, 177, 214}

2.4.7 MCA bifurcation segment: corresponds to the branching point where the insular trunks (M2s) originate.⁴⁵

Altogether, these 4 segments follow a similar surgical trajectory through the contralateral approach. The surgical pathway includes opening of the ipsilateral carotid cistern and identification of the ipsilateral vascular segments, followed by the anterior communicating complex, dissection of multiple arachnoid adhesions between the inferior frontal lobe and the contralateral optic nerve until the contralateral carotid and Sylvian cisterns are exposed with their respective vascular segments. Segments distal to the MCA bifurcation are not reachable or feasible to be approached contralaterally because of the deep and narrow surgical corridor^{40, 135}.

2.5 Techniques for proximal arterial control

Proximal arterial control before aneu-

rysm dissection and clipping is a basic principle during IA surgery. Proximal control allows softening of the aneurysm sac during the dissection, clipping and mobilization of the aneurysm.^{8, 9, 56} Additionally, it prevents copious bleeding obscuring the surgical field during unexpected intraoperative rupture.

2.5.1 Proximal control at the neck and exposure of the proximal cervical ICA

Neck dissection and exposure of the cervical ICA is a well establish technique to obtain proximal vascular control while treating ipsilateral and contralateral aneurysms due to the relatively easy access to the cervical ICA. This technique is the simplest and safest way to achieve proximal control before starting the craniotomy.^{8, 9, 26, 39} This procedure carries a small risk of general complications and it requires performing an additional skin incision.

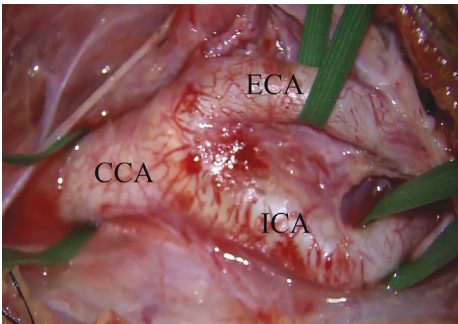
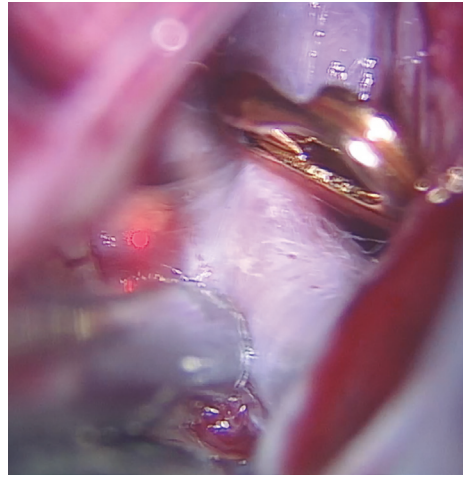


Figure 19. Right side carotid exposure for proximal vascular control (CCA common carotid artery, ICA internal carotid artery, ECA external carotid artery)

2.5.2 Temporary clipping and contralateral drilling of the anterior skull base

Anterior clinoidectomy is a well-known skull base technique to improve exposure and to obtain proximal control of ipsilateral aneurysms in the

ophthalmic, clinoidal and cavernous segments of the ICA. However, the surgical trajectory through a contralateral approach is different encountering the medial aspect of the contralateral optic canal and tuberculum sellae before the ICA. Therefore, it is required in particular cases to drill off parts of the optic canal or tuberculum sellae to improve surgical exposure that would allow temporary clipping of the parent artery to achieve proximal vascular control.^{58, 100,}



187

Figure 20. Temporary clipping on the right ICA for proximal arterial control

2.5.3 Adenosine induced-transient cardiac arrest

Systemic flow arrest by pharmacological mechanisms (adenosine, sodium nitroprussiate) or invasive procedures (open chest-circulatory arrest) has been previously described to obtain proximal control of complex aneurysm, during intraoperative rupture or deep located aneurysms.^{71, 118, 159, 187} The main principal of these procedures is to induce profound hypotension leading to a decrease in the intramural

pressure of the aneurysm, softening the aneurysm sac and making it amenable for safe clip placement.^{71, 118, 159, 187} Adenosine is an endogenous purine nucleoside widely used for cardiac arrhythmias due to its negative bromotropic and dro-tropic effects, as well as its relative short half- life.^{119, 156} Transient cardiac arrest induced by adenosine has been used during cardiac surgery, embolization of arteriovenous malformations, complex aneurysms and intraoperative aneurysm rupture.^{10, 11, 13, 29, 38, 71, 73, 78, 106, 117, 119, 129, 150-152, 156, 159, 195, 197, 221}



Figure 21. Transient cardiac arrest induced by adenosine during clipping of an aneurysm

2.6 Outcome measurements and prognosis

Several classifications have been used in neurosurgery to assess patient's post-operative outcome, including the Glasgow outcome scale (GOS) specifically described for cranial trauma, the Karnofski classification for neoplasms, and the modified Rankin scale (mRS) designed for patients with strokes.^{17, 95, 168-170} Among these scales, the most widely used in cerebrovascular neurosurgery is the mRS. The Rankin scale was initially described by Rankin in 1957, and later refined by Bonita and Beaglehole resulting in the mRS.^{17, 168-170} This scale included seven categories starting in (0) for asymptomatic patients to (6) for dead (Table 2). While measuring neurosurgical outcomes through the mRS, the most frequent cutoff is based on functional dependency. Thus, considering a mRS > 3 as a dependent functional outcome.¹⁷⁶ The cerebrovascular surgical field lacks on a proper classification to assess postoperative outcomes as compare with other surgical specialties such as orthopedics, and spine surgery among others.^{64, 66, 205, 211} The actual tendency is to implement patient-reported outcomes (RPO) in order to assess from both points of view (patients and physicians) postoperative outcomes and patient's satisfaction.^{175, 176}

0	No symptoms.
1	No significant disability. Able to carry out all usual activities, despite some symptoms.
2	Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities.
3	Moderate disability. Requires some help, but able to walk unassisted.
4	Moderately severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted.
5	Severe disability. Requires constant nursing care and attention, bedridden, incontinent.
6	Dead.

Table 2. Modified Rankin Scale (mRS)

3. Aims of the study

1. To identify anatomical and radiological parameters for a contralateral approach to internal carotid artery-ophthalmic segment aneurysms. (Study I)
2. To identify anatomical and radiological parameters for a contralateral approach to bilateral middle cerebral artery aneurysms (Study II)
3. To analyze the outcome and surgical results on aneurysms treated through a contralateral approach (Study I and II)
4. To describe the transient cardiac arrest induced by adenosine as an alternative to obtain proximal vascular control during a contralateral approach (Study III)

4. Patients, Materials and Methods

We retrospectively collected data from the Helsinki Intracranial Aneurysm Database, which includes 10021 patients with 14153 IAs evaluated by the Department of Neurosurgery at the Helsinki University Hospital since 1937, with a current catchment area of 1.8 million people. The study cohort included patients with ICA-opht segment aneurysms and bMCA aneurysms treated through a contralateral approach between January 1998 and December 2013. We excluded patients treated before 1998 because imaging strategy and availability were more variable at that time. Patients with bilateral aneurysms different than MCA were excluded as well as distal MCA aneurysms. Altogether, the study population comprised of 68 patients with ICA-opht aneurysms and bMCAs treated through a contralateral microsurgical approach.

Data were collected with the approval of the local university ethics committee (469/E0/04 HUCH). A commercially available software package was used for data analyses (SPSS for Mac, version 21.0 [2012]; SPSS, Inc, Chicago, Illinois). The variables were expressed as medians and quartiles when appropriate. They were correlated with the chi-square test, Mann-Whitney U Test, and Pearson correlations when appropriate, with a P value of .05 considered significant.

Study I

(Contralateral approach to internal carotid artery ophthalmic segment aneurysms: angiographic analysis and surgical results for 30 patients) analyzed 30 patients with ICA-opht segment aneurysms treated through a contralateral approach.

Study II

(Contralateral approach to bilateral middle cerebral artery aneurysms: comparative study, angiographic analysis, and surgical results) included 51 patients harboring bMCAs. Of those patients, only 38 underwent a contralateral microsurgical approach

Study III

(Transient cardiac arrest induced by adenosine: A tool for contralateral clipping of internal carotid artery-ophthalmic segment aneurysms) included 8 patients with 8 ICA-opht segment aneurysms treated through a contralateral approach requiring transient cardiac arrest induced by adenosine to obtain proximal vascular control and to soften the aneurysm sac.

4.1 Publication I - Contralateral approach to internal carotid artery ophthalmic segment aneurysms: angiographic analysis and surgical results

4.1.1 Patients

We retrospectively identified 268 patients harboring ICA-opht segment an-

eurysms treated at Helsinki University Hospital from January 1957 to December 2012. Among these patients, 30 patients underwent a contralateral approach from January 1998 to December 2012. Contralaterally approached patients harbored a total of 56 IAs. Table 3 reports demographics and characteristics of the patients and aneurysms.

		(n)	%
Total number of patients		30	100%
Sex distribution			
	Female	25	83%
	Male	5	17%
Age at diagnosis (years); (range)			
	Median	45 years	
	Range	19-79 years	
			100%
	Patients with single aneurysms	15	50%
	Patients with multiple aneurysms (bilateral aneurysms)	15	50%

Table 3. Characteristics of patients with ICA-opt segment aneurysms treated through a contralateral approach

4.1.2 Imaging

The diagnostic imaging methods included DSA, CTA, MRA and/or a combination of each images modality. Patients' preoperative neurological condition was assessed according to the Hunt-Hess scale (H-H) without correction for general disease.⁸⁸ For each contralaterally approached aneurysm, we measured the maximal length, neck width, and size of the aneurysm. Additionally, we evaluated the presence of calcifications, irregularities, complex anatomy and secondary pouches, shape (saccular vs. fusiform), and the projection of the aneurysm dome in relation to the parent artery

To identify specific radiological parameters that would favor a contralateral approach for ICA-opt segment aneurysms, we measured the distance in millimeters between the medial walls of both ICAs at the level of the tuberculum sellae, and the distance between the tip of both anterior clinoidal processes (ACPs) on CT and CTA. Among the patients with available brain MRI, we determined the interoptic distance (distance between both optic nerves at the beginning of the optic canal), and the prechiasmatic distance (distance from the anterior border of the chiasm to the planum sphenoidale).

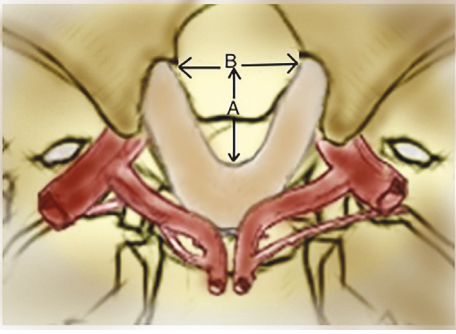


Figure 22. Schematic drawing of the prechiasmatic (A), interoptic (B) distances, and location of ACP in relationship with the ICA.

4.1.3 Analysis and follow-up

Patients included in this series underwent surgical clipping of the ipsilateral and/or contralateral aneurysm through a LSO.⁸⁰ For contralateral ICA-optic segment aneurysms, the surgical trajectory required dissection through the interoptic space or above the contralateral optic nerve to expose the aneurysm dome. Clinical outcome was assessed at discharge and at 3 months follow-up and it was classified according to the mRS as good (mRS 0-3) or poor (mRS 4-6), based on the ability to walk without assistance. All the patients underwent post-operative radiological studies to assess patency of the parent vessel and aneurysm occlusion rate.

4.2 Publication II - Contralateral approach to bilateral middle cerebral artery aneurysms: comparative study, angiographic analysis, and surgical results

4.2.1 Patients

Between January 1998 and December 2013, we retrospectively analyzed 51 patients with bMCA aneurysms (excluding distal MCA aneurysms) treated at the Helsinki University Hospital. A total of

38 patients underwent a unilateral and contralateral approach for treatment of bMCAs in one session, and 13 patients underwent bilateral craniotomies in one or two-stages. The median age at diagnosis for patients treated through contralateral approach was 58 years, whereas the median age at diagnosis for patients with bilateral craniotomies was 52 years.

4.2.2 Imaging

The majority of anatomical measurements were obtained through CTA images. We determined angiographic variables such as maximal aneurysm length, width, shape (fusiform/saccular) and size. Additionally, we analyzed the presence of calcifications, secondary pouches, wall irregularities, and the projection of the aneurysm dome in relation to the parent artery and Sylvian fissure.

To establish angiographic characteristics that would favor a contralateral approach for MCA aneurysms, we measured the lengths of the contralateral A1 and M1, the height in millimeters of ICabif above the planum sphenoidale, and the distances between both ICabifs.

4.2.3 Analysis and follow-up

We divided into two separate groups. Group 1 included patients with bMCA aneurysms treated through a contralateral microsurgical approach during the same setting. Whereas, group 2 included patients with bMCA aneurysms treated through bilateral craniotomies at one or second-stage surgery. These groups were obtained to assess the feasibility of the contralateral approach over bilateral craniotomies.

As previously mentioned, all patients underwent a LSO for the treatment of the IAs. For contralateral MCA aneurysms, the surgical trajectory follows a tangential view through the contralateral ICA bifurcation followed by the dissection of the contralateral Sylvian vallecule and cistern. The mRS was used to measure outcomes, evaluated at discharge and at 3-months follow-up, using the previous classification based on the ability to walk without assistance. In addition, surgical time was compared for both surgical approaches.

4.3 Publication III - Transient cardiac arrest induced by adenosine: A tool for contralateral clipping of internal carotid artery-ophthalmic segment aneurysms

4.3.1 Patients

We retrospectively identified 8 patients who underwent clipping of an ICA-opht segment aneurysm through a contralateral approach and received intravenous bolus of adenosine to achieve proximal vascular control, between January 1998 and December 2013 at Helsinki University Hospital. The study population comprised of 6 women and 2 men, with a median age at diagnosis of 35 years (range 24-58 years).

4.3.2 Technique for contralateral clipping during Transient Cardiac arrest induced by Adenosine

Following the standard anesthesia setup of our clinic¹⁶⁷, we maintained the anesthesia with remifentanyl and propofol infusions. A standard LSO approach is performed as previously described by Hernesniemi et al.⁸⁰ The

intracranial work starts subfrontally with gently retraction over the ipsilateral frontal lobe, following by dissection of the ipsilateral carotid cistern, prechiasmatic cistern and arachnoid adhesions of the contralateral ICA and contralateral optic nerve. When the ICA-opht segment aneurysm is completely dissected, a permanent pilot clip is placed partially open around the aneurysm neck and a dose (dose 0.2-0.4 mg/kg) of adenosine is administered intravenously by a neuroanesthesiologist to soften the aneurysm sac. Then, when asystole is achieved the aneurysm sac is pulled gently by suction and the permanent clip is fully applied. Continuous electrocardiogram (ECG) and arterial blood pressure are monitored before, during and after adenosine arrest.

4.3.3 Imaging and analysis

We retrospectively analyzed the clinical data and radiological images. The extracted clinical variables included age, gender, aneurysm characteristics, preoperative neurological status, previous medical history, presence of comorbidities, adenosine characteristics (doses, asystole time, heart rate and blood pressure before and after administration), and complications. The complications were divided into general complications and adenosine related complications. The mRS was used for the description of the outcome at discharge, 3-month, and 1-year follow-up. Good outcome was classified as mRS 0-2, moderate outcome as mRS 3-4, and poor outcome as mRS 5-6. This represents a more rigorous outcome assessment than in previous studies (Study I and II).

5. Results

5.1 Characteristics of ICA-opht segment aneurysms treated through a contralateral approach

5.1.1 Morphology and size

All 30 aneurysms located on the contralateral side were unruptured and saccular in shape. Six (20%) patients presented with SAH due to a ruptured ipsilateral aneurysm, whereas the remaining 24 (80%) patients had no history of bleeding. Among the patients with SAH, the median length of the contralateral aneurysm was 3.6 mm (range, 2.9-7.2 mm) and the median neck diameter was 4.2 mm (range, 3-5 mm). In patients without SAH, the median length of the contralateral aneurysm dome was 3.3 mm (range, 1.3-8 mm) and the median neck diameter was 2.9 mm (range, 1.5-4.7 mm). None of the contralateral ICA-opht segment aneurysms contained wall irregularities, calcifications or secondary pouches.

Aneurysm size distribution had the following pattern: 29 (93%) aneurysms were smaller than 7 mm, and 1 (7%) aneurysm had medium size (7-14 mm).

5.1.2 SAH distribution

The modified Fisher grade for patients with SAH due to a ruptured ipsilateral aneurysm had the following distribution: grade 1 in 1 patient (17%), grade

2 in 3 patients (50%), and grade 3 in 2 patients (33%). All patients with an SAH harbored multiple IAs. Table 4 summarizes aneurysm characteristics of this segment

Aneurysm side			
	Left	21	70%
	Right	9	30%
Number of patients with SAH according modified Fisher Scale			
	Grade 1	1	17%
	Grade 2	3	50%
	Grade 3	2	33%
Aneurysm shape			
	Saccular	30	100%
Aneurysm size distribution			
	Small (< 7 mm)	29	93%
	Medium (7-14 mm)	1	7%

Table 4. Characteristics of ICA-opht segment aneurysms approached through a contralateral side

5.1.3 Specific radiological parameters for a contralateral approach

The most frequent dome projection for a contralateral approach to ICA-opht segment aneurysm was superome-

dial (n=23, 77%), followed by medial (n=4, 13%) and superior (n=3, 10%). The interoptic distance had a median of 10.5 mm (range, 7.6-15.9), the prechiasmatic distance had a median of 5.7 mm (range 3.4-8.7 mm). Table 5 summarizes specific radiological parameters for this segment.

Possible projections	Medial, superior and superomedial
Distance between both ICA at the planum sphenoidale	Median 14.7 mm (range 10.4-21.4 mm)
Distance between both ACP	Median 26.2 mm (range 22.5-31.5 mm)
Prechiasmatic distance	Median 5.7 mm (range 3.4-8.7mm)
Interoptic distance	Median 10.5 mm (range 7.6-15.9 mm)

Table 5. Specific radiological parameters for a contralateral approach for ICA-opht segment aneurysms

5.1.4 Single aneurysms for contralateral clipping

The contralateral approach was used to clip 15 single ICA-opht segment aneurysms. All of these aneurysms were unruptured, saccular in shape and without secondary pouches or calcifications. The median neck diameter was 2.9 mm (range, 2.2-4.7 mm) and the median aneurysm dome length was 3.3 mm (range, 1-7-8 mm). The most frequent projection was superomedial (n=12, 80%).

5.1.5 Bilateral aneurysms treated through a unilateral craniotomy

The remaining 15 patients in this series with ICA-opht segment aneurysms treated through a contralateral approach harbored 41 BIAs. The most frequent associated aneurysm were MCA aneurysms (n=9, 35%) followed by ICA-opht segment aneurysms (n=6, 24%) and PcoA aneurysms (n=5, 19%).

5.2 Characteristics of bMCA aneurysms treated through a contralateral approach and bilateral craniotomies

5.2.1 Morphology and size

As previously mentioned, patients with bMCA aneurysms were divided into two groups. Group 1 (bMCA aneurysms treated through a unilateral – contralateral approach), and group 2 (bMCA aneurysms treated through bilateral craniotomies). In group 1 patients, the median neck diameter of the ipsilateral MCA aneurysm was 2.9 mm (range: 1.6-7.7 mm) and the median length of the aneurysm dome was 4.2 mm (range: 1.6-15.5 mm). The contralateral MCA aneurysm had a median length of 3.8 mm (range: 1.9-19 mm) and a median neck diameter of 3 mm (range: 1.3-6.1 mm). Table 6 reports aneurysm characteristics of this group.

In group 2 patients, the median neck diameter of the first approached aneurysm was 4.7 mm (range: 2.3-11.6) and the median dome length was 7.9 mm (range: 2.2-20.4 mm). Whereas, the contralateral aneurysm (treated by a second craniotomy) had a median length of 3.8 mm (range: 2.5-12.3 mm), and a median neck diameter of 3 mm (range: 2.4-6.8). Table 7 demonstrated aneurysm features of this group.

The majority of contralaterally approached MCA aneurysms were saccular in shape (n= 37, 97%). On the other hand, patients treated through bilateral craniotomies had contralateral MCA aneurysms that were saccular (n=7, 54%), bilobular (n=4, 32%), irregular (n=1, 7%), and with calcifications (n=1, 7%). The saccular shape of the aneurysm was a very significant feature while selecting a contralateral approach over bilateral craniotomies (P<.01). No statistical significance existed between the length of the aneurysm (P=.7), and projection (P=.1) when comparing surgical approaches.

Table 6. Aneurysm features of group 1 with bMCA aneurysms

Aneurysm size		Ipsilateral aneurysm		Contralateral aneurysm	
		(n)	%	(n)	%
	Small < 7 mm	28	74%	32	84%
	Medium 7-14 mm	8	21%	5	13 x%
	Large 14-21 mm	2	5%	1	3%
	Giant > 21 mm	0	0%	0	0%
Shape					
	Saccular	32	84%	37	97%
	Fusiform	1	3%	0	0%
	Irregular	0	0%	0	0%
	Calcification	1	3%	0	0%
	Bilobular	4	10%	1	0%
	Complex anatomy	0	0%	0	0%
Projections					
	Inferior	5	13%	22	58%
	Superior	8	21%	2	5%
	Lateral	17	45%	3	8%
	Anterior	8	21%	11	29%
Location					
	M1	14	37%	16	42%
	MCA bifurcation	24	63%	22	58%
Total		38	100%	38	100%

Table 7. Aneurysm features of group 2 with bMCA aneurysms

Aneurysm size		First aneurysm treated (n)		Contralateral aneurysm (n)	
				%	%
	Small < 7 mm	6	46%	11	85%
	Medium 7-14 mm	4	31%	2	15%
	Large 14-21 mm	3	23%	0	0%
	Giant > 21 mm	0	0%	0	0%
Shape					
	Saccular	6	46%	7	54%
	Fusiform	0	0%	0	0%
	Irregular	5	38%	1	7%
	Calcification	0	0%	1	7%
	Bilobular	1	8%	4	32%
	Complex anatomy	1	8%	0	0%
Projections					
	Inferior	0	0%	4	31%
	Superior	1	8%	3	23%
	Lateral	9	70%	1	8%
	Anterior	3	22%	5	38%
Location					
	M1	1	8%	11	85%
	MCA bifurcation	12	92%	2	15%
Total		13	100%	13	100%

5.2.2 SAH distribution

Out of all patients with bMCA aneurysms, 14 patients presented with SAH. Among them the HH scale was represented in the following manner: grade 2 (n = 4, 29%), grade 3 (n = 5, 35%), grade 4 (n = 4, 29%), and grade 5 (n = 1, 7%).

5.2.3 Specific radiological parameters for a contralateral approach

In group 1, the median length of the contralateral M1 was 14.2 mm (range: 4.6-21 mm) and the median length of the contralateral A1 was 13.2 mm (range: 6-19.8 mm). In group 2, the median length of the contralateral M1 was 15.4 mm (range: 7.1-33 mm) and the median length of the contralateral A1 was 13.5 mm (range: 9.7-20 mm). No statistical significance existed between these measurements when comparing both approaches ($P = .06$ and $.79$, respectively). The height of ICA in the contralateral group had a median of 11 mm (range: 3.4-16 mm) and the distance between both ICAbif had a median of 30 mm (range: 11.5-35.6 mm). Table 8 reports the specific radiological parameters for a contralateral approach to MCA aneurysms.

5.2.4 Associated aneurysms

Table 8. Specific parameters for MCA aneurysms approached through a contralateral side

Parameter	Contralateral group
Length of A1	Median 13.2 mm (range 6-19.8 mm)
Length of M1	Median 14.2 mm (range 4.6-21 mm)
Height of ICA bifurcation	Median 11 mm (range 3.4-16 mm)
Distance between both	Median 30 mm (range 11.5-35.6 mm)
ICA bifurcation	

The total cohort of 51 patients harbored 145 IAs. Among the patients, 24 had 2 aneurysms (only bMCA aneurysms), and 27 had 3 or more aneurysms. The most frequent associated aneurysms were AcoA aneurysms (n=13, 30%), followed by additional MCA aneurysms (n=11, 26%) and basilar aneurysms (n=7, 16%).

5.3 Surgical results and outcomes after a contralateral approach

5.3.1 Outcome of ICA-opht segment aneurysms

All except one ipsilateral and contralateral aneurysm underwent direct microsurgical clipping. No intraoperative rupture or complications occurred during a contralateral approach. In one patient, a contralateral aneurysm had to be coagulated and wrapped with muscle and fibrin glue due to the small size and thin wall. In this series, a total of 28 (93%) patients had good outcome at discharge and at 3-month follow-up. Among the patients with good outcome, 27 had mRS 0-2 and 1 patient had mRS 3. The remaining 2 (7%) patients of this series had poor outcome at discharge and at 3-month follow-up. These 2 poor outcomes were associated to post-hemorrhagic vasospasm and to poor preoperative clinical grade.

Outcome at discharge and 3-month

follow-up associated with preoperative HH scale (P = .01 and P = .05), modified Fisher scale (P = .01 and P = .05), and preoperative presentation of the aneurysm (P = .03 and P = .02).

5.3.2 Complications of ICA-opht segment aneurysms

Of the 30 patients treated in this group, 2 (7%) patients had postoperative CSF leak that was resolved using a spinal drainage, 2 (7%) suffered local wound infections, and 1 (3%) patient had postoperative hemianopia. None of the patients demonstrated brain infarction after a contralateral approach, and no mortality appeared at 3-month follow-up related to the surgical approach.

5.3.3 Outcomes of bMCA aneurysms treated through a unilateral-contralateral approach

Among the 38 patients comprised in this group, 36 patients underwent clipping of the ipsilateral and contralateral MCA aneurysms without intraoperative rupture or surgical complications. Two ipsilateral aneurysms were wrapped with muscle and fibrin glue because of complex anatomical configuration. Of the patients harboring bilateral unruptured aneurysms, 24 (86%) patients had good outcome and 4 (14%) had poor outcome at 3-month follow-up, 1

patient was lost to follow-up. Among the patients with good outcomes, 23 had mRS 0-2 and 1 patient had mRS 3. Of the 4 poor outcomes, 2 patients had ipsilateral ischemia, 1 patient died due to postoperative hematoma, and 1 patient had contralateral ischemia.

Of the patients presented with SAH due to an ipsilateral ruptured aneurysm, 7 (78%) patients had good outcomes (mRS 0-2), and 2 (22%) patients had poor outcomes at 3-month. Poor clinical outcomes were completely related to poor preoperative clinical grade. The total median surgical time was 120 minutes (range: 75- 255 minutes).

5.3.4 Complications of bMCA aneurysms treated through a unilateral-contralateral approach

The most common complications after a unilateral-contralateral approach for bMCAs were anosmia in 5 patients (13%), hyposmia in 3 patients (8%), followed by general complications such as secondary hydrocephalus in 4 patients (11%), meningitis in 2 patients (5%), wound infection in 2 patients (5%), ipsilateral ischemia in 2 patients (5%), and contralateral ischemia in 1 patient (3%).

5.3.5 Outcomes of bMCA aneurysms treated through bilateral craniotomies

Among the patients harboring bilateral unruptured MCA aneurysms, 6 (75%) patients had good outcomes (mRS 0-2), and 2 (25%) patients had poor outcomes at 3-month follow-up. Of the 2 poor outcomes, 1 patient died because of bilateral ischemia and 1 patient experienced unilateral ischemia. All 5 (100%) patients who presented with SAH due to the first approached aneu-

rysm had good outcomes at 3-month follow-up. The median surgical time for this group was 212 minutes (range: 115-371 minutes).

5.3.6 Complications of bMCA aneurysms treated through bilateral craniotomies

The most frequent complications were secondary hydrocephalus in 2 patients (15%), ipsilateral ischemia in 2 patients (15%), bilateral ischemia in 1 patient (8%) and meningitis in 1 patient (8%).

5.4 Transient cardiac arrest induced by adenosine: proximal vascular control during a contralateral approach for ICA-opht segment aneurysms

5.4.1 Preoperative Clinical Condition

All the 8 patients harbored unruptured ICA-opht segment aneurysms. The preoperative clinical presentation had the following distribution: 6 patients presented as incidental findings, 1 patient underwent screening due to familial history of IAs, and 1 patient due to a previous SAH (harboring multiple aneurysms). Of the total, 6 patients had single ICA-opht segment aneurysms, and 2 patients had 2 or more aneurysms. Patient comorbidities included: 1 patient with systemic erythematous lupus, and 1 patient with hypercholesterolemia and drug-treated hypertension. This patient cohort was free of cardiac or pulmonary pathologies. Preoperative ECG showed normal sinus rhythm in all patients.

5.4.2 Aneurysms characteristics

In all 8 cases, the aneurysms were saccular in shape and unruptured. The median aneurysm neck diameter was 2.9 mm (range: 2.2-3.6) and the medi-

an length of the aneurysm dome was 3 mm (range: 1.7-4.2 mm).

5.4.3 Adenosine characteristics

As previously described, the reason for administering adenosine 5 mg/ml (Adenosine Life Medical) was the inability to obtain proximal vascular control by temporary clipping of the ICA. A total of 5 patients received single boluses of adenosine, whereas the remaining 3 patients received multiple doses. The median single dose of adenosine was 22.5 mg (range, 5-50 mg). The asystole time range between 20-40 seconds after adenosine administration.

5.4.4 Surgical results and postoperative cardiac and neurological outcome

No intraoperative aneurysmal rupture occurred in this series. All except 1 aneurysm underwent direct microsurgical clipping. One aneurysm had to be wrapped with muscle and fibrin glue due to the thin wall and small size. No abnormal ECG or clinical signs of cardiac complications appeared after adenosine administration, thus precluding the necessity of measurement of troponin T levels.

At discharge, 3-month and 1-year follow-up all the patients demonstrated good outcomes. No ischemic brain events were identified.

6. Discussion

6.1 Characteristics of aneurysms treated through a contralateral approach

6.1.1 Size and Morphology

Aneurysm characteristics such as size, shape, morphology, and location should be considered when planning treatment through a contralateral microsurgical approach. In our series, the majority of aneurysms located on the contralateral ICA-opt segment (n=30, 100%), and on the contralateral MCA segment (n=37, 97%) were smaller than 14 mm. This is in concordance with previously described series reporting that aneurysm size for safe contralateral clipping should be less than 15 mm.^{26-28, 40, 41, 58, 83, 84, 92, 130, 135, 148, 180, 189, 204} Larger aneurysms may require complex surgical techniques that might be dangerous and challenging to perform at the depth of the surgical corridor of a contralateral approach. In addition, it may require extensive mobilization and retraction of important neurovascular structures such as optic nerves, frontal lobes and olfactory nerves among others that may lead to new postoperative deficits.

A common parameter while choosing a contralateral approach is the shape of the aneurysm. In our series, all except one of the contralaterally approached aneurysms located on the ICA-opt seg-

ment and along the MCA were saccular in shape and simple in morphology, enabling their treatment with simple clip configurations. As previous authors have suggested, aneurysms displaying complex anatomy, presence of calcifications, irregular wall, and fusiform shapes should be treated with an ipsilateral approach.^{40, 41, 84, 92, 135, 180, 189}

All contralaterally approached aneurysms in our series were unruptured. This is not surprising since managing a ruptured aneurysm through a contralateral approach may be challenging due to poor visualization of the vessel and aneurysm secondary to presence of hematoma, and higher risk of intraoperative rupture, thus suggesting that ruptured aneurysms should be approached from the ipsilateral side.^{40, 41, 92, 135, 180}

6.1.2 Multiple IAs and SAH

CT and CTA may be helpful to identify the rupture side on patients with SAH and harboring multiple IAs.^{5, 142} In our series, the ruptured aneurysm was approached through an ipsilateral craniotomy leaving the unruptured aneurysm to be treated through a contralateral approach when possible. A contralateral approach should not be performed in patients with severe SAH, tight brain, and edema to avoid the risk of inflic-

ing additional injuries to the surrounding neurovascular structures as a result of excessive brain retraction and difficult dissection.^{92, 135, 180} In cases where the ipsilaterally approached aneurysm failed to be the rupture side, we recommend performing a second craniotomy on the other side to secure the bleeding source, and to avoid the consequences of approaching a ruptured aneurysm without early proximal control.^{92, 135, 180}

6.1.3 Aneurysm dome projection

Planning a contralateral microsurgical approach requires careful aneurysm selection and preoperative planning. The anatomy of the contralateral surgical corridor is different compared when approaching an aneurysm through an ipsilateral craniotomy. Three-dimensional CTA reconstructions in addition to skull base landmarks allow the neurosurgeon to maintain orientation and to mimic the contralateral surgical trajectory providing a better understanding of the surrounding anatomy and the aneurysm itself.

According to our analysis and in concordance with previous authors, contralateral clipping of ICA-opht segment aneurysms is possible when the aneurysm dome is projecting medially, superomedially and superiorly.^{58, 84, 92, 100, 135, 137, 204, 213} Aneurysms arising from the lateral wall of this segment and projecting laterally or superolaterally should be approached through an ipsilateral craniotomy, and in this way avoiding the consequences of significant manipulation of the contralateral optic nerve, lack of proximal vascular control, and poor visualization of the aneurysm if approached through a contralateral craniotomy.^{40, 135}

Unruptured MCA aneurysms projecting anteriorly, superiorly, inferiorly and laterally may be exposed through a contralateral approach. For every particular projection of this segment, special technical nuances should be taken into account: a) Superiorly projecting aneurysms may be adherent to the arachnoid of the Sylvian fissure, requiring careful dissection of the aneurysm, as it is performed through the inner segment of the Sylvian fissure and in a deep surgical corridor, b) Inferiorly projecting aneurysms: small perforators arising from the medial wall of the MCA make their dissection difficult due to the risk of unexpected injury, c) Laterally projecting aneurysms: in these cases the dome is oriented along the axis of the MCA, making their exposure more challenging as it is in the surgeon's line of view.^{28, 40, 41, 83, 92, 135, 180, 189} Finally, a downward directed contralateral MCA trunk aneurysm is easier to dissect and expose from a contralateral approach.

6.1.4 Radiological criteria to evaluate the contralateral corridor

The surgical route for contralateral clipping of ICA-opht segment aneurysms is performed through the interoptic space and prechiasmatic cistern. In some cases, the presence of a prefixed chiasm or short interoptic distance limits the accessibility to these aneurysms.^{40, 215} Thus, increasing the risks of optic nerve or chiasm damage. In our series, contralateral clipping of ICA-opht aneurysm was feasible through the interoptic route in patients with a median prechiasmatic cistern of 5.7 mm and a median interoptic space of 10.5 mm, in concordance with previous results reported by Kakizawa et al.¹⁰⁰ Parameters such as the distance between ACI, and

the distance between both ICAs did not show statistical significance or importance while performing a contralateral approach. In a contralateral surgical view, the contralateral ICA is always closer to the surgeon than the contralateral ACP.

The contralateral approach for MCA segment aneurysms have been previously ill advised because of the deep and narrow surgical corridor. However, its feasibility is related to the length of the contralateral A1 and M1 segments. Previous anatomical and radiological studies reported the length of the contralateral M1 between 14 and 20 mm, and the length of the contralateral A1 between 7.2 and 18 mm.^{92, 177, 180} In our study, the contralateral approach for MCA aneurysms was possible when the median length of M1 was 14 mm (range: 5-21 mm) and the median length of A1 was 13.2 mm (range: 6-20 mm), in agreement with previously published data.^{92, 177, 180}

In the era of minimally invasive approaches and retractor-less brain surgery, an apparent disadvantage of the contralateral approach is the need for significant frontal lobe retraction. Conceptually speaking, the ICAbif represents the highest point of the circle of Willis, and this height may be indicative of the potential need of frontal lobe retraction for access to aneurysms located beyond the contralateral ICAbif (Figure 23). In our series, a median height of the ICAbif of 11 mm (range 4-16 mm) allowed performing the contralateral approach without excessive frontal lobe retraction.

6.2 Proximal Vascular control during a contralateral approach

6.2.1 Proximal vascular control

Proximal vascular control is one of the fundamental principles in aneurysm surgery. The most common technique to achieve proximal arterial control requires application of a temporary clip onto the parent artery.

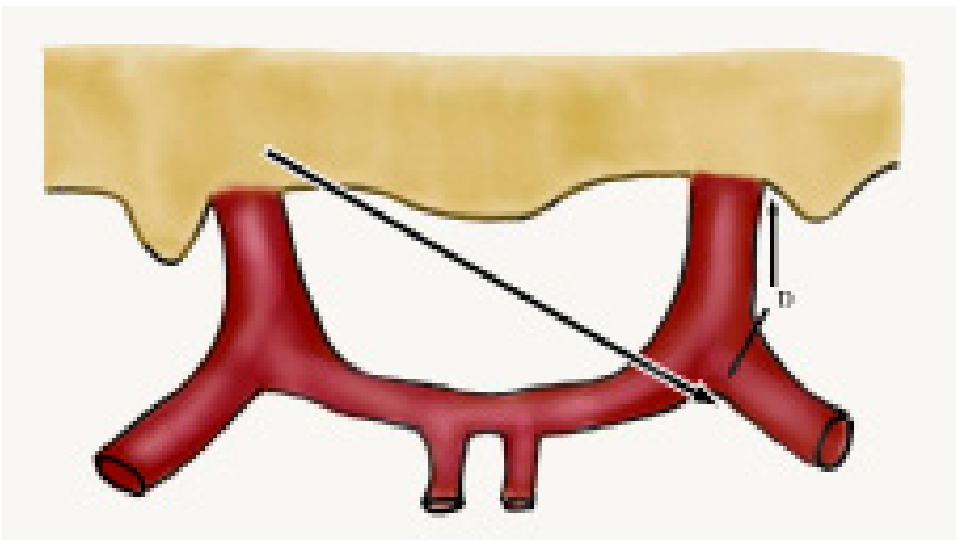


Figure 23. Demonstrating the surgical trajectory and the relationship between the height of ICA and the frontal lobe. (D. Height of the ICA bifurcation).

When approaching ICA-opht segment aneurysms through a contralateral craniotomy, one could achieve proximal control by placing a temporary clip on the parent ICA. However, this may be difficult to achieve in the following scenarios: a) a narrow surgical corridor due the dissection performed through the interoptic route, b) inexistent space between the planum sphenoidale and the aneurysm or parent artery, requiring drilling of the anterior skull base in a deep surgical field, c) presence of calcifications on the parent artery leading to risk of injuring the ICA and the aneurysm.^{58, 100, 135} As an alternative to temporary clipping in these situations, transient cardiac arrest induced by adenosine allows short systemic flow arrest resulting in softening of the aneurysm sac for pilot clip application. In our series, transient cardiac arrest induced by adenosine was used in 8 patients where temporary clipping of the parent artery was impossible, providing that short but valuable amount of time for safe clipping in a deep and narrow surgical field.

In contrast, when approaching MCA aneurysms through a contralateral craniotomy, proximal control of the parent vessel is relatively straightforward because the dissection follows the M1 trunk. However, complete parent vessel isolation by placing temporary clips on the M2 segment is difficult due to the length of the surgical trajectory.^{92, 180}

6.2.2 Advantages of adenosine-induced transient cardiac arrest

The advantages of adenosine-induced transient cardiac arrest during aneurysm clipping include: a) Temporary total flow arrest into the parent vessel, decreasing transmural pressure of the

aneurysm facilitating the circumferential dissection of the sac and decreasing the risk of intraoperative rupture.^{10, 11, 13, 129} b) Complete recovery of the base-line parameters (i.e. heart rate and blood pressure) with practically no need of additional medications due to the adenosine short half-life. In our series, all 8 patients that underwent adenosine administration reached their normal blood pressure levels within 5-10 minutes of adenosine administration.^{10, 11, 13, 73, 119, 151} c) Multiple administrations, adenosine may be used repeatedly after recovery from the initial dose. In order to achieve longer asystole time or continue with the exposure and dissection of the aneurysm, 3 patients in our series received multiple doses of intravenous adenosine without any adverse effects. These findings are in line with similar previous reports.^{10, 11, 13, 119, 129} d) Safety without compromising cardiac or neurological outcome. This is demonstrated by our results, since we experience no cardiac or brain ischemic complications in patients that received intravenous bolus of adenosine.^{10, 11, 13, 106, 129} However, careful patient selection (absence of coronary ischemic disease or pulmonary pathologies) is the most important aspect while inducing cardiac arrest during a contralateral approach.

6.3 Outcomes and complications of a contralateral approach

6.3.1 ICA-opht segment aneurysms

Microsurgical treatment of IAs is technically challenging and demanding. This difficulty increases when the aneurysm is approached through a contralateral craniotomy requiring expertise and careful preoperative planning. In our series, no intraoperative rupture

or complications occurred during microsurgical clipping, similar to previous published data.^{40, 41, 92, 135, 180, 189}

Vadja et al²⁰⁴ reported a failure rate of 5% of contralateral clipping mainly caused by arachnoid adhesions surrounding the aneurysm neck, complex shape, deep location or in the presence of a pre-fixed chiasm. These results are similar to ours, where a contralateral clipping of ICA-opht segment aneurysms was possible in 97% of cases.

Contralateral clipping of ICA-opht segment aneurysms has a reported good patient outcome rate of 74% to 85% of cases that is similar to our results, where 93% of patients reported good outcomes at 3-month follow-up.^{58, 100, 204, 213} In our series, good postoperative outcomes positively correlated with better preoperative HH grade, unruptured aneurysm status, and lower modified Fisher scale grade. These findings were expected since good neurological outcome is associated with a good HH grade, and smaller amount of intracranial hemorrhage.¹²⁸ Overall, our findings suggest that in carefully selected patients, the contralateral approach to unruptured aneurysms does not increase morbidity.

6.3.2 Advantages and surgical nuances for ICA-opht aneurysms

a) The contralateral approach can be used to treat single or bilateral ophthalmic segment aneurysms. In case of bilateral opht segment aneurysms presenting with SAH, the ruptured aneurysm should be approached first through an ipsilateral craniotomy leaving the unruptured aneurysm to be exposed through the contralateral ap-

proach. In cases of bilateral unruptured aneurysms, the most complex and larger aneurysm is approached through the ipsilateral craniotomy, whereas the simpler aneurysm is exposed via the contralateral approach, as also demonstrated in our series.¹³⁸

b) Compared to the ipsilateral approach, the contralateral approach can be performed with a lower risk of visual deficits (3%)^{58, 135} as the surgical trajectory via the contralateral approach spares the need of performing anterior clinoidectomy since the ICA-opht segment is always more medial than the ACP.

6.3.3 bMCA aneurysms

Similar to our previous results with ICA-opht segment aneurysms, no intraoperative rupture or complications occurred during clipping of MCA aneurysms using the contralateral approach.^{92, 135, 180}

Contralateral clipping of MCA aneurysms has a reported rate of good outcomes of 83% to 91% in previous series. Similar to our results, that demonstrated good outcomes in 86% at 3-month follow-up.^{92, 135, 180} The presence of only bMCA aneurysms was an additional factor that associated with good outcomes in our series, similarly to results published by de Sousa et al.⁴¹

6.3.4 Advantages and surgical nuances for treating bMCA aneurysms

a) The contralateral approach for bMCA aneurysms in selected patients spares performing an additional craniotomy and all its related phases (bilateral opening and closure).

b) It decreases the costs and surgical time. As demonstrated in our series,

the surgical time decreases 43% when compared to performing bilateral craniotomies.^{92, 180}

c) It requires careful and detailed preoperative planning (aneurysms characteristics), and mimicking the surgical trajectory through a contralateral view to successfully perform a contralateral clipping. The main concept of a contralateral craniotomy is to approach the most complex and difficult aneurysm through the ipsilateral side leaving the simplest one to be treated via the contralateral approach.

6.3.5 Disadvantages

a) The contralateral approach can be used only in selected cases, considering all the previous aneurysms characteristics (unruptured, saccular shape, simple and regular wall, small size, and different projections) and specific parameters for each vascular segment.

b) The risk of olfactory dysfunction after performing a contralateral approach for MCA aneurysms have been described in up to 58% of cases.¹⁵⁴ This represented a frequent complication (total 21%, including anosmia 13% and hyposmia 8%) in our series as well. However, the risk of experiencing olfactory dysfunction is not unique to the contralateral approach, since it may occur even in a unilateral approach for ipsilateral anterior circulation aneurysms in up to 4% of cases. In order to reduce the rate of olfactory disturbances, prolonged retraction of the frontal lobe should be avoided, and sharp dissection of the arachnoid adhesions surrounding the olfactory nerve should be used to allow better mobilization of the frontal lobe.

6.4 Limitations

As previously mentioned the cerebrovascular surgical fields lacks on specifics scales to measure patient's outcome and prognosis. In our study, outcome was assessed based on the mRS using as cutoff point functional dependency of the patient (mRS > 3 based in the ability to walk without assistance). However, during the review process of the articles it was found logic that a closer assessment makes more sense for the evaluation of good outcomes. While performing this more detailed classification, patients with contralateral ICA-ophth aneurysms showed 90% (previously 94%) of good outcome (comprising only mRS 0-2), and patients with bMCA aneurysms showed 82% (previously 84%) of good outcome (only mRS 0-2). Thus, using a more detailed classification the results did not change dramatically. Additionally, another limitation was the possibility to report a long-term clinical and angiographic follow-up of our series. However, this was impossible since these data were unavailable during our collection process.

Some strengths of this study are: a) up to date the largest world case-series on a contralateral approach for anterior circulations aneurysms, b) represents the surgical experience of a single surgeon and the evolution of surgical technique.

6.5 Future trends for contralateral approaches

Surgical instruments, techniques and visualization systems have evolved over the years. The current tendency of using less invasive techniques, and the development of endoscope-assisted aneurysm surgery or purely endoscopic aneurysm surgery increases the feasibility and accessibility of deep and narrow surgical fields through small ports improving outcomes, occlusion rate of aneurysms and cosmesis. Aneurysms surrounded by important neurovascular structures have been widely treated by endovascular methods improving surgical outcomes and minimizing invasiveness. In near future, microsurgical treatment of aneurysms will be limited to those impossible to treat endovascularly, and when required this will be performed through even smaller approaches or purely endoscopic aneurysm surgery.

7. Conclusion

I.

The feasibility of the contralateral approach for ICA-opht segment aneurysms depends on general and specific anatomical parameters of the aneurysm itself and the vascular segment. This approach can be used to treat small, unruptured and saccular single or bilateral aneurysms projecting medially, superior and superomedially when the prechiasmatic and interoptic distances are satisfactory

II.

The contralateral approach for bMCA aneurysms is safe and feasible to perform with acceptable morbidity and mortality in selected patients requiring careful preoperative planning and identification of the aneurysms characteristics and anatomical/radiological landmarks of the contralateral operative corridor.

III.

During a contralateral approach for ICA-opht aneurysms, transient cardiac arrest induced by intravenously administered adenosine is a useful technique to achieve flow arrest and softening of the aneurysm sac for safe dome dissection and clipping. Its use is not associated with worse neurological outcome in selected patient.

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A handwritten signature in black ink, appearing to read 'Francisco Muñoz', written diagonally across the page.

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