Intraoperative measurement of arterial blood flow in complex cerebral aneurysms' surgery

Studio flussimetrico intra-operatorio nel clipping degli aneurismi complessi

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NEUROSURGERY | University Hospital of Padova

NO CONFLICT OF INTEREST TO DISCLOSE

Summary

Monitoring in aneurysm surgery
Flow-assisted microsurgical clipping
Flowmetry in complex aneurysms
Is it enough?
Neurophysiological monitoring and ICG
Multimodal strategy
New perspectives about flowmetry

Monitoring in aneurysm surgery

Monitoring in aneurysm surgery

Why?

Surgical Outcome

Authors	Period	n. patients	n. centers	Deficits post-op	Ischemic injury	Monitoring technique
Higashida et al. (USA)	2000	2535	429	11%	6%	No
Kim et al (Korea)	2006	1696	48	7%	7%	No
Amin-Hanjani et al (USA)	2000-2003	103	1	2%	2%	Flowmetry (All patients)
Kjung-Il Jo et al (Korea)	2008-2012	610	1	2%	4.5%	SSEP+MEPs (All patients)
Choi HH etal	2014-2017	386	1	1.8%	2.1%	SSEP+MEPs (All patients)

Causes of cerebral ischemia during aneurysm surgery

1. *Artery clip stenosis or occlusion*
2. *Temporary clipping*
3. *Retraction injury or ischemia*
4. *Intraoperative aneurysm rupture*
5. *Mechanical injury to artery*
6. *Decrease in mean systemic blood pressure*
7. *Intraoperative vasospasm*
8. *Embolic intraoperative events*

Raabe et al, J Neurosurg Sci 2016

Aims of intra-operative monitoring in aneurysm surgery

To improve patient outcome by decreasing ischemic injury related to surgery

. Identification of potentially wrong current strategy

. Surgical strategy can be changed within right time (reversible phase)

Causes of cerebral ischemia during aneurysm surgery

1. *Artery clip stenosis or occlusion*
2. *Temporary clipping*
3. *Retraction injury or ischemia*

Efficacy of Intra-operative Monitoring

4. *Intraoperative aneurysm rupture*
5. *Mechanical injury to artery*
6. *Decrease in mean systemic blood pressure*
7. *Intraoperative vasospasm*
8. *Embolic intraoperative events*

Raabe et al, J Neurosurg Sci 2016

Monitoring in aneurysm surgery

Why?

How?

Monitoring Techniques for Prevention of Procedure-Related Ischemic Damage in Aneurysm Surgery

Susanna Bacigaluppi[1,2], Marco Fontanella[3,4], Pirjo Manninen[5], Alessando Ducati[3], Giovanni Tredici[1], Fred Gentili[2]

...ent Surgery-Related Ischemic Damage in Aneurysm Treatment

	Detection Characteristics										
Monitoring Modality	**Depth**	**Area**	**Parent Vessel Stenosis**	**Perforator Occlusion**	**Sac Remnant**	**Feature Monitored**	**Frequency**	**Timing**	**Open/Closed Sky**	**Invasiveness**	**Cost**
DSA	S and D	B	Yes	Yes	Yes	Flow	1–2 times	UERJ (intraop)	O and C	High	High
CT angiography (intraop)	S and D	B	Yes	No	Yes	Flow	1–2 times	UERJ (intraop)	O and C	Low	High
ICG videoangiography	S	B	Yes	Yes*	Yes	Flow	Repeatable	intraop UERJ	O	Low	Low
CT perfusion (intraoperative)	S and D	B	Yes, indir	Yes, indir	No	Flow	1–2 times	UERJ (intraop)	O and C	Low	High
Micro-Doppler	S	R	Yes, indir	Yes	Yes	Flow	Repeatable	intraop UERJ	O	Low	Low
Transient time flowmeter	S	R	Yes, indir	No	No	Flow	Repeatable	intraop UERJ	O	Low	Low
Laser speckle contrast analysis	S	B	Yes, indir	Yes, indir	No	Flow	Intermittent	Throughout	O	Low	Low
Thermal diffusion flowmetry	S	R	Yes, indir	Yes, indir	No	Flow	Continuous	Throughout	O	Low	Low
Microdialysis and brain tissue Po_2 measurement	S	R	Yes, indir	Yes, indir	No	fx (metab)	Continuous	Throughout	O and C	High	Low
Near-infrared spectroscopy	S	R	Yes, indir	Yes, indir	No	fx (metab)	Continuous	Throughout	O and C	Low	Low
SSEP	S and D	B	Yes, indir	Yes, indir	No	fx (Nt)	Continuous	Throughout	O and C	Low	Low
BAEP	S and D	B	Yes, indir	Yes, indir	No	fx (Nt)	Continuous	Throughout	O and C	Low	Low
MEP	S and D	B	Yes, indir	Yes, indir	No	fx (Nt)	Intermittent	Throughout	O and C	Low	Low
EEG	S	B	Yes, indir	Yes, indir	No	fx (Nt)	Continuous	Throughout	O and C	Low	Low
ECoG	S (and D)	B	Yes, indir	Yes, indir	No	fx (Nt)	Continuous	Throughout	O	Low	Low

Surgical goals and intra-operative technologies

Flow monitoring techniques

- *Vessel flow visualization*
  - *ICG-videoangiography*
  - *Intra-operative DSA*
- *Ultrasonometry flow evaluation*
  - *Micro-Doppler*
  - *Transit Time Flowmetry*
- *Perfusion CT-scanning*

Function monitoring techniques

- *Neurophysiologic Monitoring (Motor & Somato-Sensory EP)*
- *Detection of Metabolic Activity (Microdialysis)*

Monitoring in aneurysm surgery

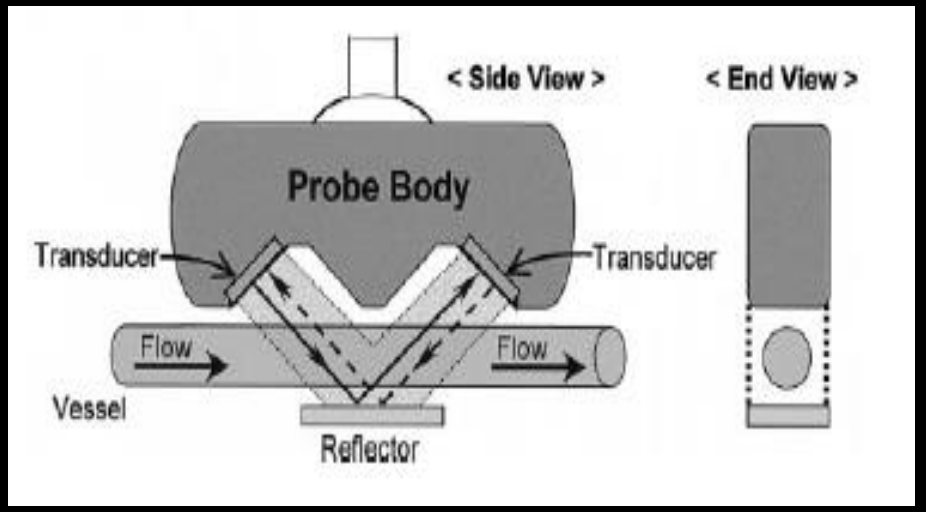
Flow-assisted microsurgical clipping

The flow probe device

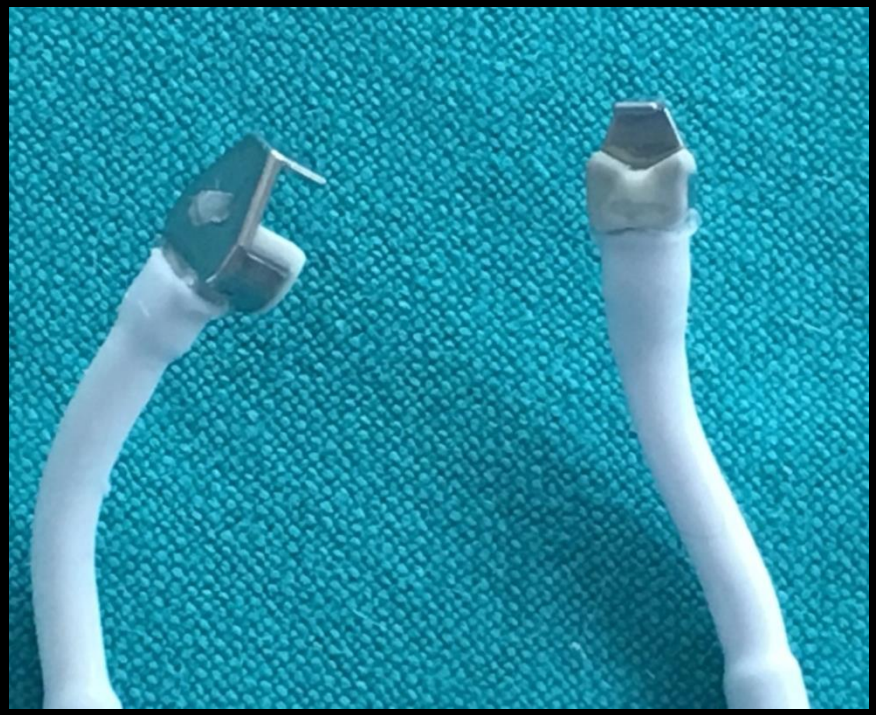
Flow sensing perivascular microprobe

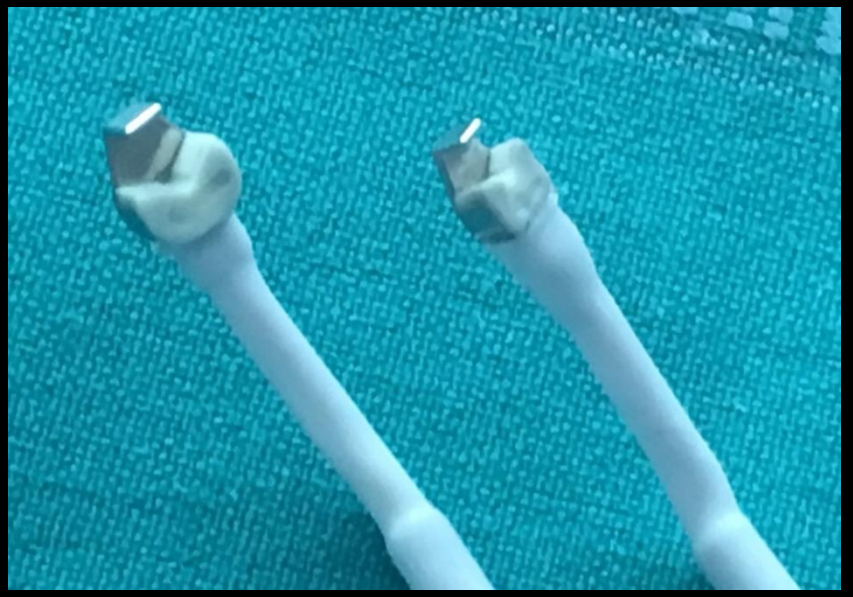
Electronic flow detection unit

The body of the probe consists of two ultrasonic transducers and a fixed acoustic reflector



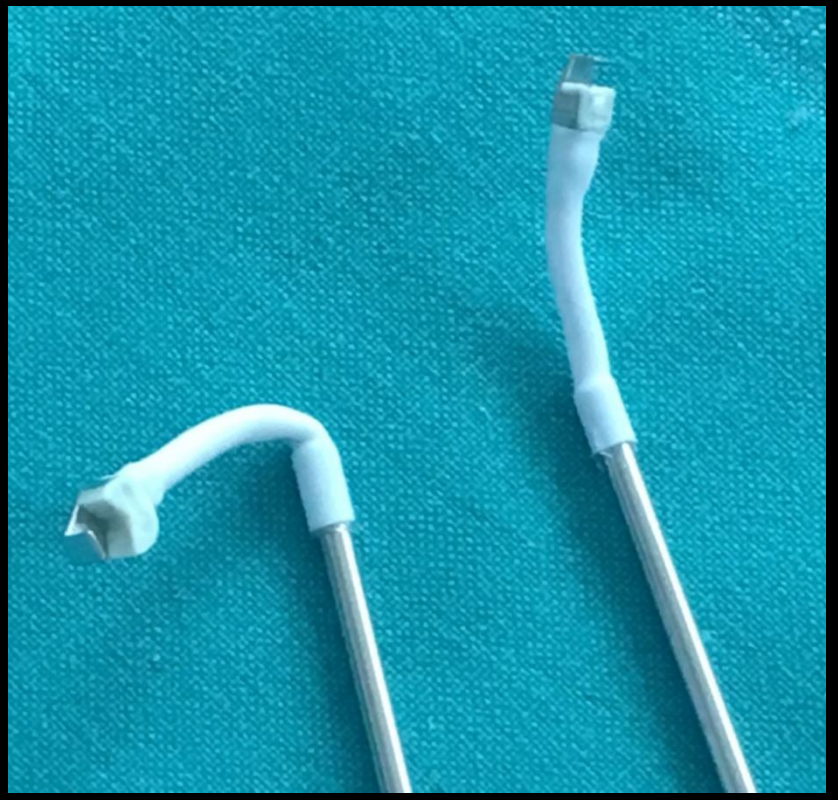
The two transducers emit and receive ultrasonic beams; once an ultrasonic beam starts from the first transducer, it reaches the reflector plate and subsequently the second transducer, and then the same happens from the second transducer to the first



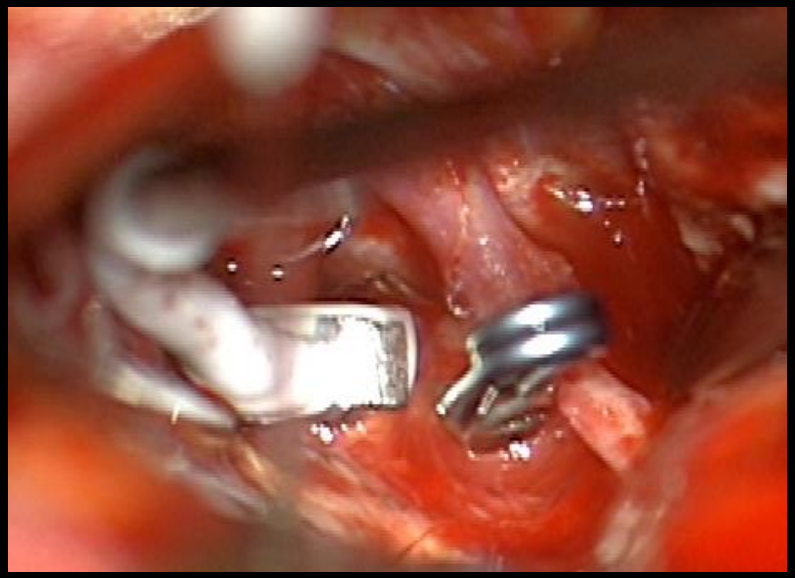


The probe is manufactured in a variety of sizes, ranging from 1.5 to 3 mm in diameter

The probe can be adapted to vessel features

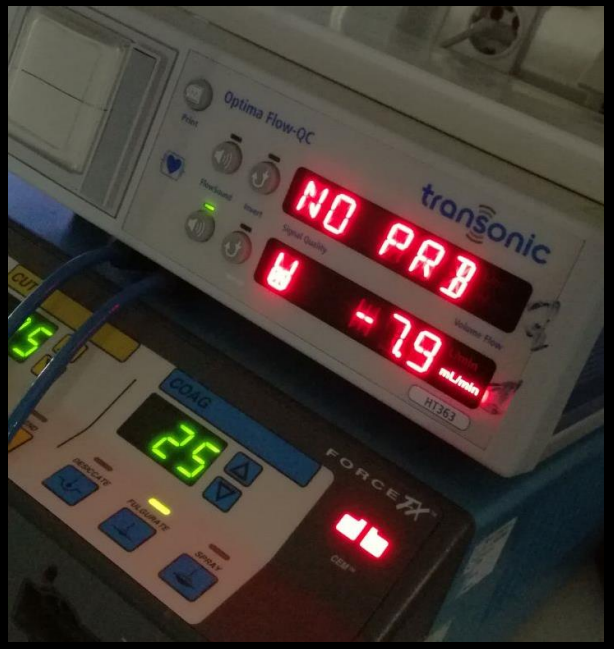


The flowmetry



Once the probe is placed around the vessel, the ultrasound beams have to intersect the vessel upstream or downstream to reach the transducers.

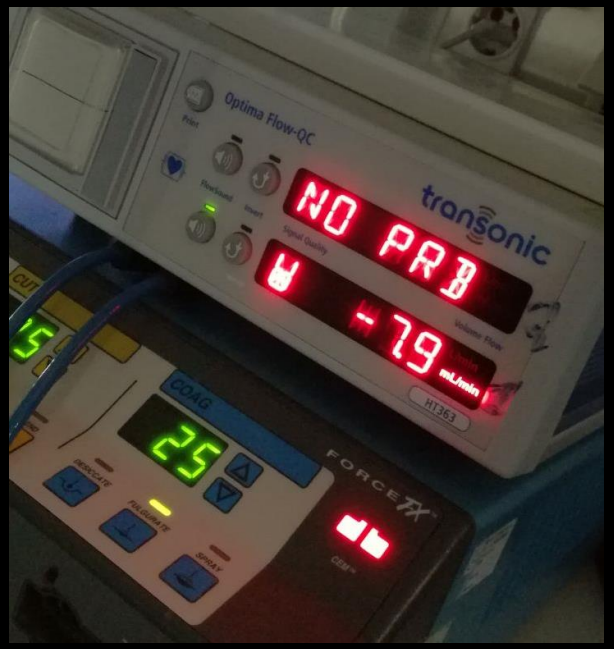
The ultrasound *transit time* is affected by the motion of flow through the vessel, and the difference between the upstream and downstream transit time is used to obtain the volume of flow (in mL/min) through the vessel insonated,which is calculated by the electronic flow detection unit



The flowmetry

Reading is influenced by:
Systemic blood pressure
End Tidal (PaCO2)

Reading is not influenced by:
Wall thickness
Heart rate
Hematocrit



Real time flow evaluation
Quantitative assessment (ml/min)
Can be easily repeated on demand

The Utility of Intraoperative Blood Flow Measurement During Aneurysm Surgery Using an Ultrasonic Perivascular Flow Probe

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OBJECTIVE: Inadvertent vessel compromise is one major cause of unfavorable outcome from aneurysm surgery. Existing strategies for intraoperative assessment of this complication have potential limitations and disadvantages. We assessed the utility of quantitative intraoperative flow measurements using the Transonic ultrasonic flow probe (Transonic Systems, Inc., Ithaca, NY) during aneurysm surgery.

METHODS: Of all aneurysms treated surgically at our institution from 1998 to 2003, 103 patients with 106 aneurysms were identified in whom intraoperative flow measurements were available for analysis. We assessed the frequency of flow compromise and clip repositioning and correlated these with postoperative angiography and stroke.

RESULTS: Significant (>25%) reduction in flow rate was apparent in 33 (31.1%) cases, and resulted in clip repositioning in 27 (25.5%), with return to baseline flow except for two cases with vessel thrombosis/dissection. In the other six cases, flow reduction was owing to spasm resolving with papaverine ($n = 3$) or responded to retractor repositioning ($n = 3$). In another six (5.7%) cases, unnecessary clip repositioning was avoided ($n = 3$) or safe occlusion of the parent vessel for trapping of the aneurysm was allowed by confirming adequate distal flow ($n = 3$). Aneurysms of the basilar, middle cerebral, anterior communicating, or carotid terminus were more likely to be associated with flow compromise (odds ratio, 4.3; $P = 0.03$). Postoperative angiography corroborated vessel patency in all cases, and no unexpected large vessel occlusions or strokes were evident.

CONCLUSION: Use of the ultrasonic flow probe provides real-time immediate feedback concerning vessel patency. Vessel compromise is easier to interpret than with Doppler, and faster/less invasive than intraoperative angiography. Intraoperative flow measurement is a valuable adjunct for enhancing the safety of aneurysm surgery

KEY WORDS: Aneurysm, Angiography, Blood flow, Flow probe

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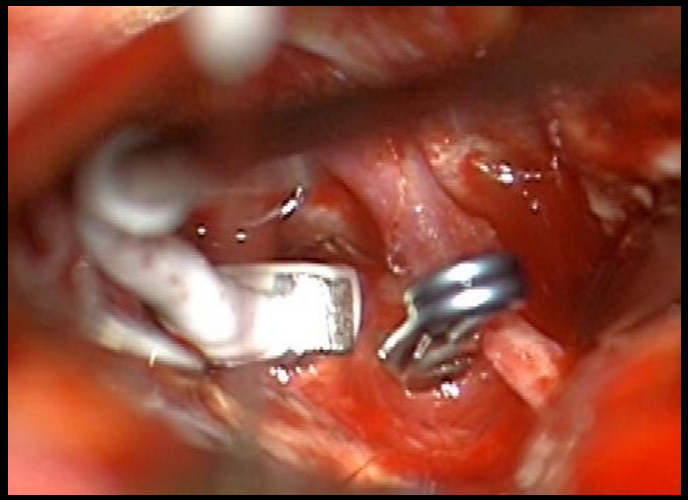
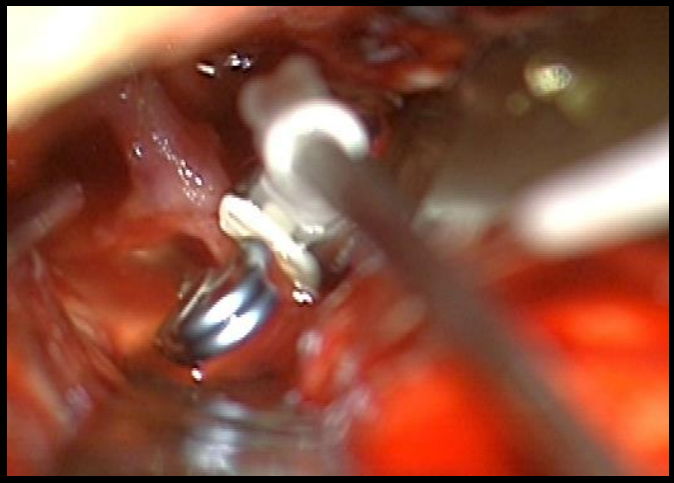
Flow drop <25% → No Stroke!

Aneurysm exposure → Flowmetry



Clipping

Flowmetry



Flow drop >25%

Flow drop <25%

Clip repositioning

Flowmetry

Flow drop >25%

Flow drop <25% → Aneurysm complete exclusion

Video #1

Flowmetry Technique
(Right MCA unruptured aneurysm)

Intraoperative Measurement of Arterial Blood Flow in Aneurysm Surgery

Alberto Pasqualin, Pietro Meneghelli, Angelo Musumeci, Alessandro Della Puppa, Giacomo Pavesi, Giampietro Pinna, and Renato Scienza

	Ruptured	Unruptured	Total
MCA	**92**	**161**	**253**
ACoA	**74**	**44**	**118**
ICA	**22**	**44**	**66**
Distal ACA	**13**	**7**	**20**
Posterior circulation	**2**	**5**	**7**
TOTAL	**203**	**261**	**464**

Table 1 Intraoperative flowmetry for cerebral aneurysms; treated in Verona and Padua (2001–2010)

	Ruptured	Unruptured	Total
MCA	83	94	177
ACoA	66	27	93
ICA	19	35	54
Distal ACA	9	5	14
Posterior circulation	2	5	7
TOTAL	179	166	345

MCA Middle cerebral artery, *ACoA* Anterior communicating artery, *ICA* Internal carotid artery, *ACA* Anterior cerebral artery

Table 2 Intraoperative flowmetry for cerebral aneurysms; treated in Verona (2011–2016)

	Ruptured	Unruptured	Total
MCA	9	67	76
ACoA	8	17	25
ICA	3	9	12
Distal ACA	4	2	6
Posterior circulation	–	–	–
TOTAL	24	95	119

MCA Middle cerebral artery, *ACoA* Anterior communicating artery, *ICA* Internal carotid artery, *ACA* Anterior cerebral artery

Intraoperative Measurement of Arterial Blood Flow in Aneurysm Surgery

Alberto Pasqualin, Pietro Meneghelli, Angelo Musumeci, Alessandro Della Puppa, Giacomo Pavesi, Giampietro Pinna, and Renato Scienza

Table 4 Basal flow values detected on cerebral arteries in patients with unruptured and ruptured aneurysms (Verona and Padua common experience, 2001–2010)

	Ruptured aneurysms	Unruptured aneurysms	*p* value
	Flow values ± SD	Flow values ± SD	
A1 tract	28.6 ± 10.9	30.9 ± 14.5	NS
A2 tract	24.7 ± 11.5	22.8 ± 10.3	NS
M1 tract	39.7 ± 14.5	39.2 ± 16.0	NS
M2 tract	21.7 ± 11.7	21.0 ± 10.6	NS
M3 tract	18.8 ± 11.0	13.5 ± 5.6	NS
Supraclinoid ICA	50.2 ± 23.0	42.0 ± 19.9	NS
Pericallosal A.	15.1 ± 4.6	14.9 ± 6.3	NS
PICA		12.2 ± 7.1	–

SD standard deviation, *NS* $p > 0.05$

Intraoperative Measurement of Arterial Blood Flow in Aneurysm Surgery

Alberto Pasqualin, Pietro Meneghelli, Angelo Musumeci, Alessandro Della Puppa, Giacomo Pavesi, Giampietro Pinna, and Renato Scienza

Clip repositioning was needed in 18% of patients
48% ruptured vs 52% unruptured

Clip Replacements were done
In the SAH group in 62% on MCA , 31% on ACoA, and 7% on ICA aneurysms
In the unruptured aneurysms in 82% in MCA, 12% in ACoA,6% in pericallosal aneurysms

Complete flow restoration was obtained in 75% of patients

Monitoring in aneurysm surgery

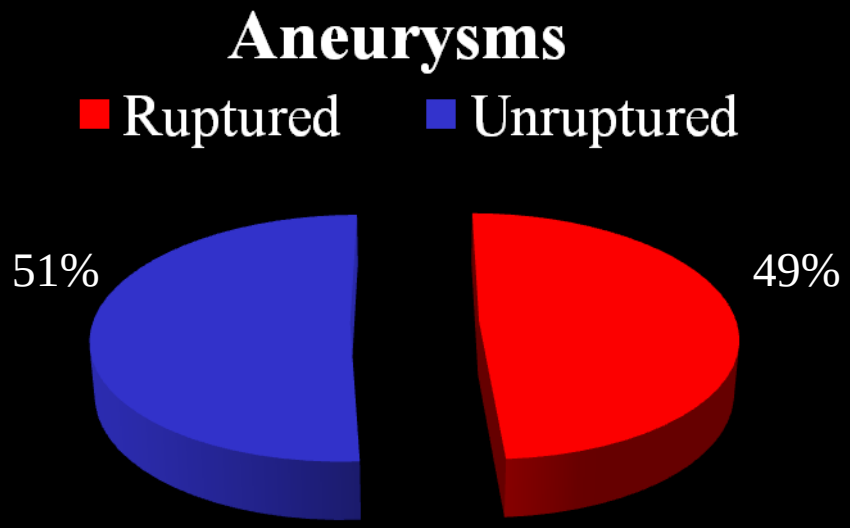
Flow-assisted microsurgical clipping

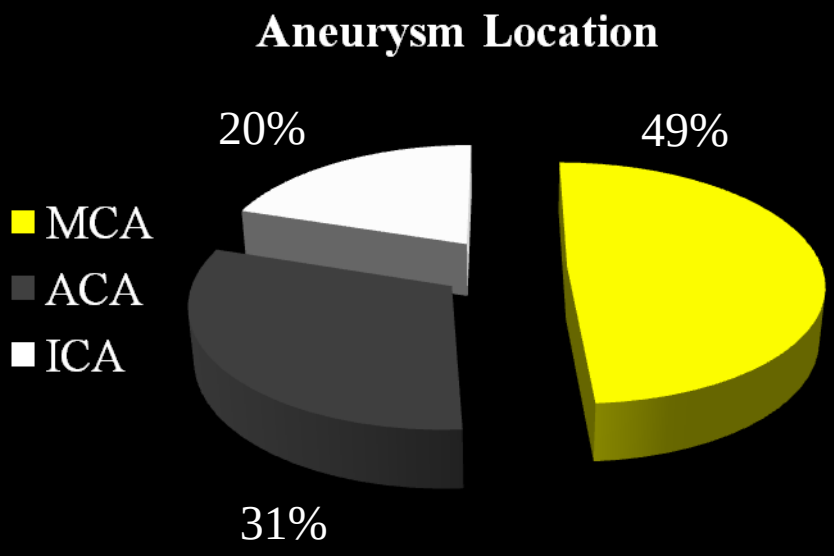
Flowmetry in complex aneurysms

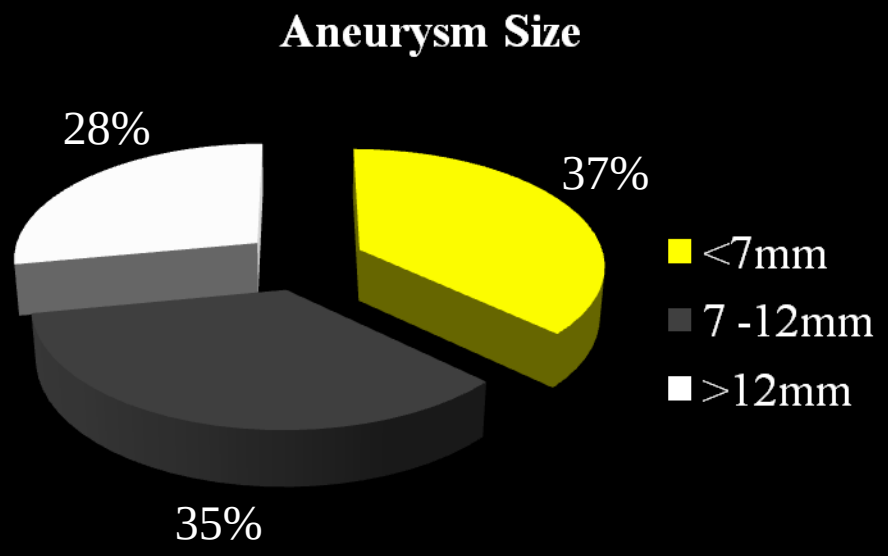
Last 5 years personal experience on flowmetry

Retrospective analysis 2013-2017
183 patients/207 aneurysms
1020 flow assessments by flowmetry

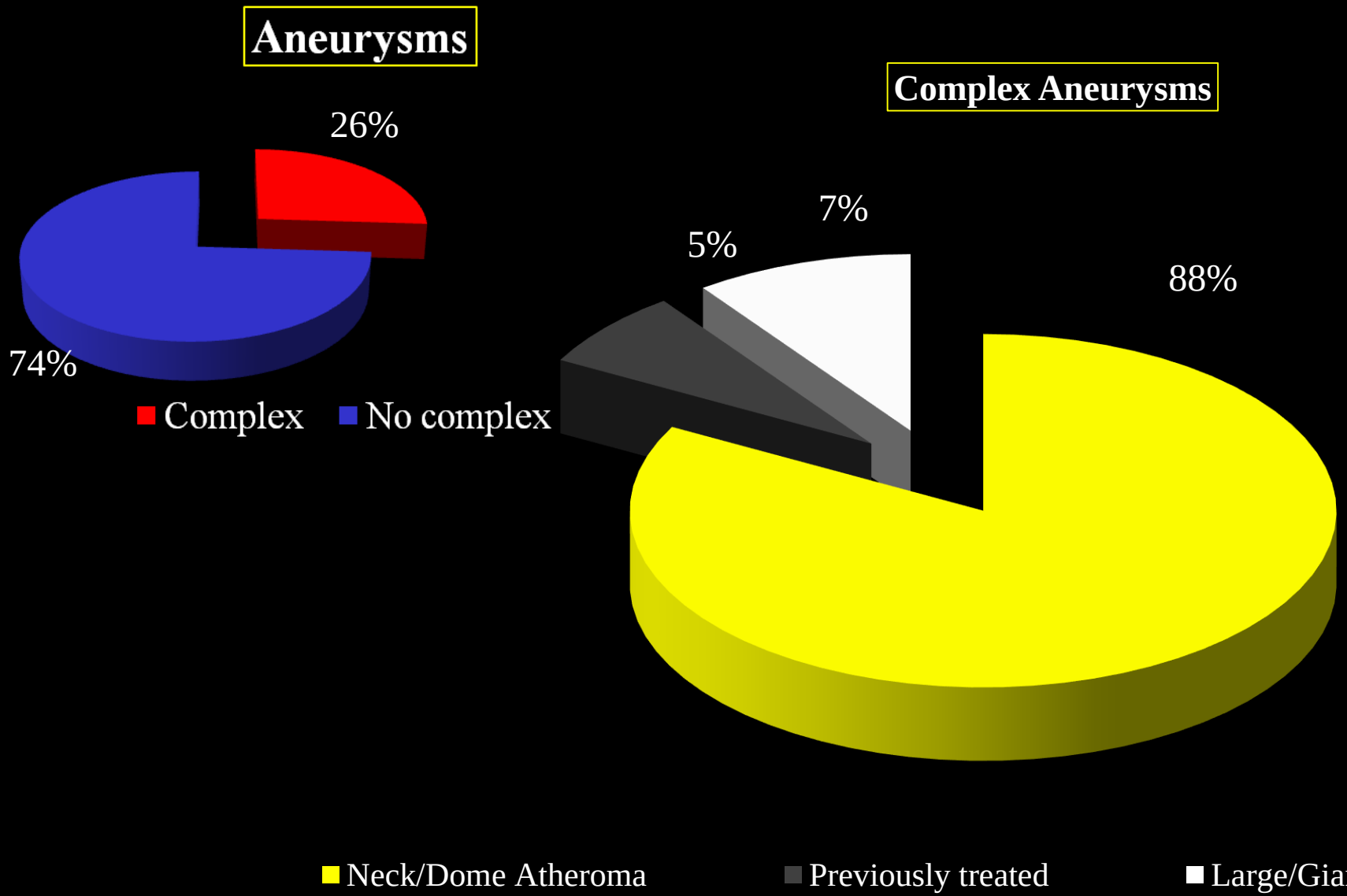
Last 5 years personal experience







Last 5 years personal experience – Complex Aneurysms



Neck/Dome Atheroma (Calcification)

Key points

High risk of vessel strain/distorsion due to neck/dome stiffness → vessel occlusion during clip positioning

Video #2

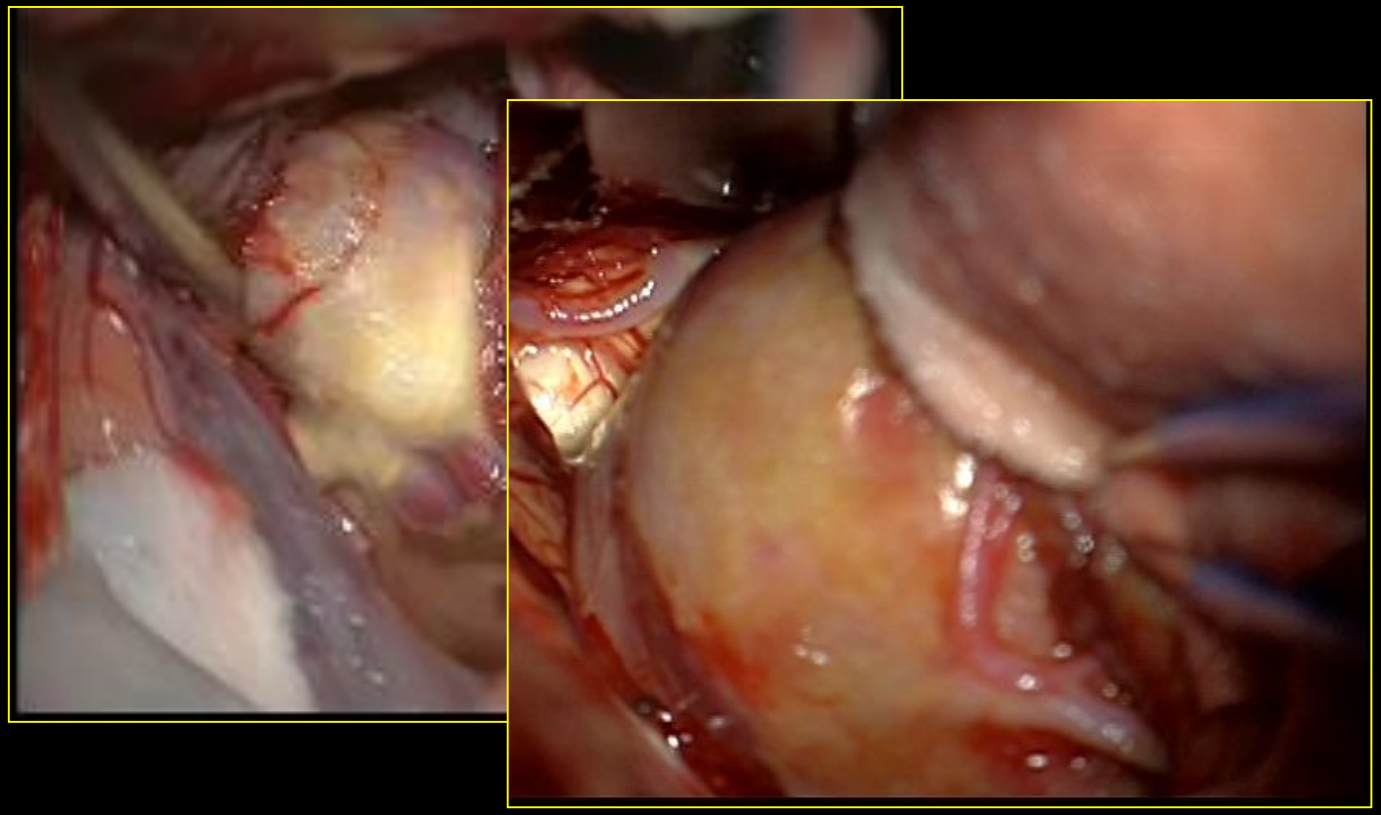
Neck/Dome atheroma
(Left MCA unruptured aneurysm)

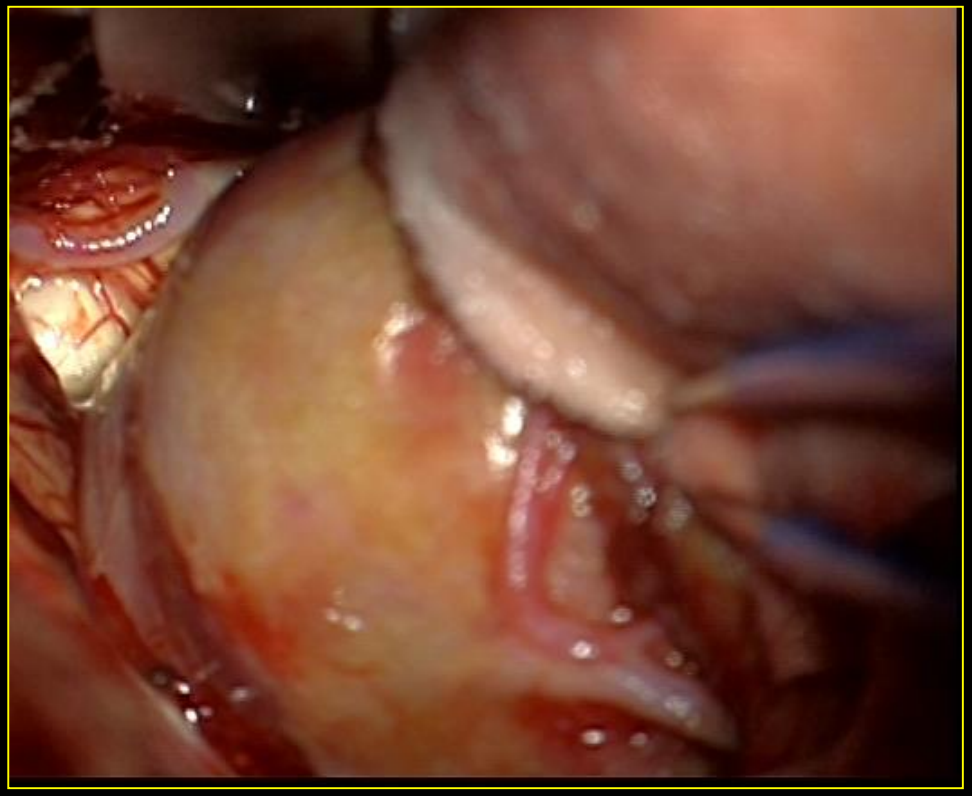
Video #3

Neck/Dome atheroma
(ACoA unruptured aneurysm)
(with single right ICA)

Neck/Dome Atheroma (Calcification)

Large/Giant Aneurysms





Key points

1.High flow/Dome thrombus push clip down on the neck occluding branch arteries

2. Need of neck reconstruction after thrombus reduction/removal

Video #4

Giant aneurysm
(Left MCA unruptured aneurysm)

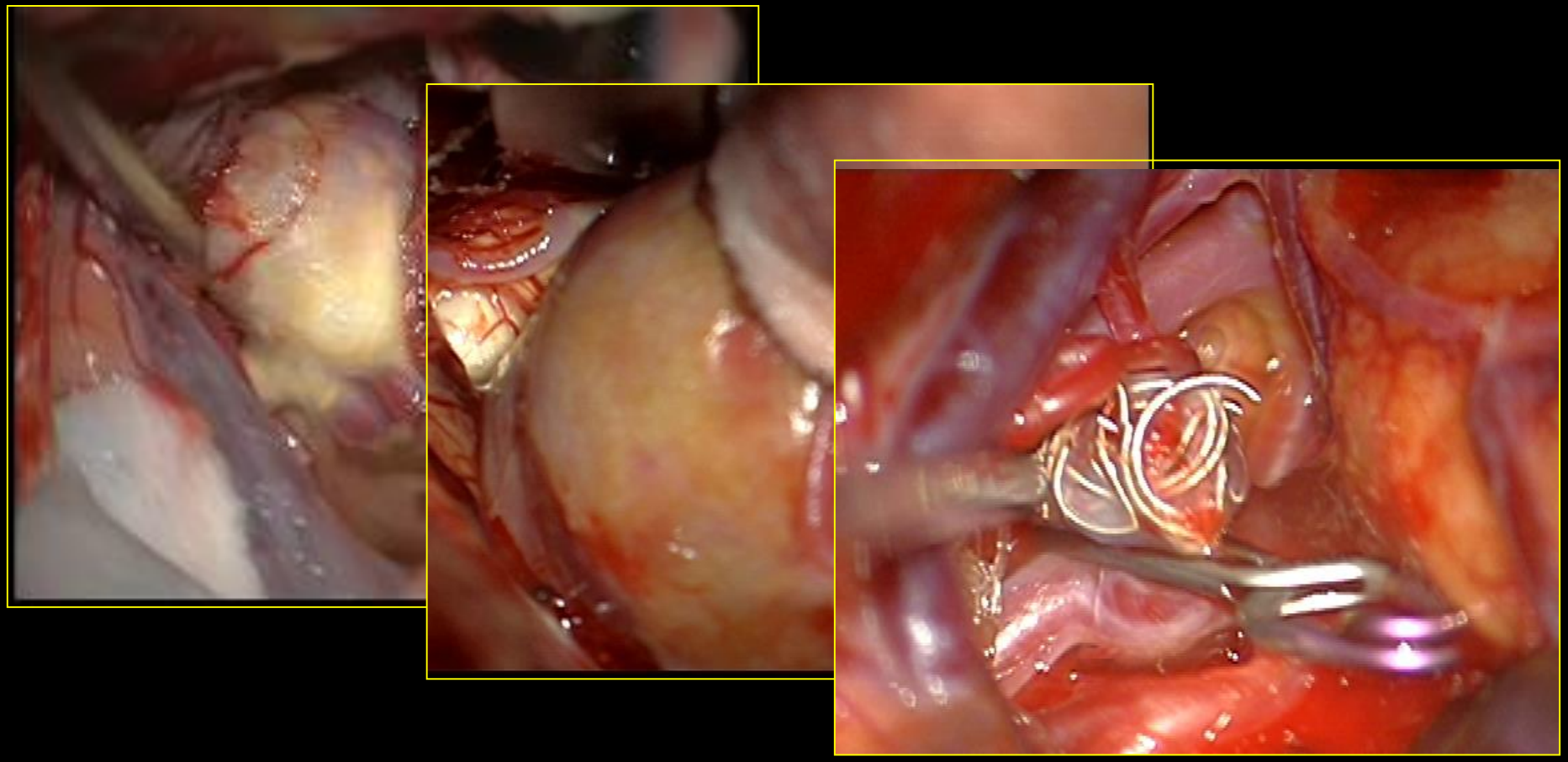
Video #5

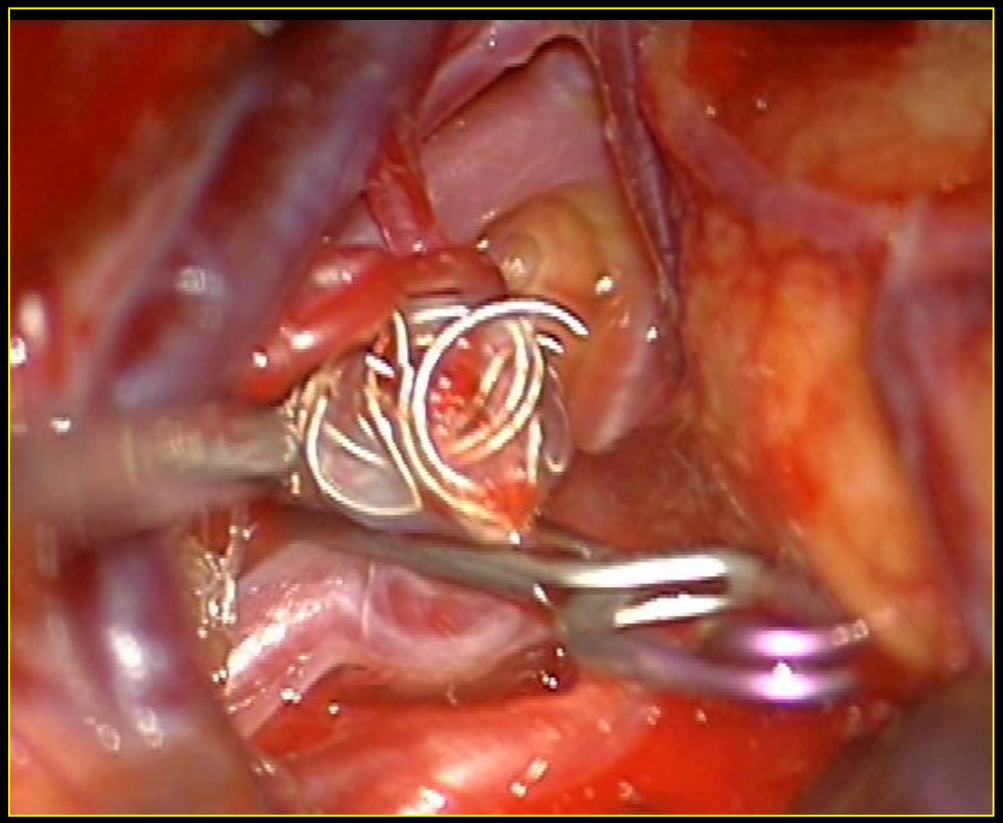
Large aneurysm
(Left COFT unruptured aneurysm)

Neck/Dome Atheroma (Calcification)

Large/Giant Aneurysms

Previously treated Aneurysms





Key points

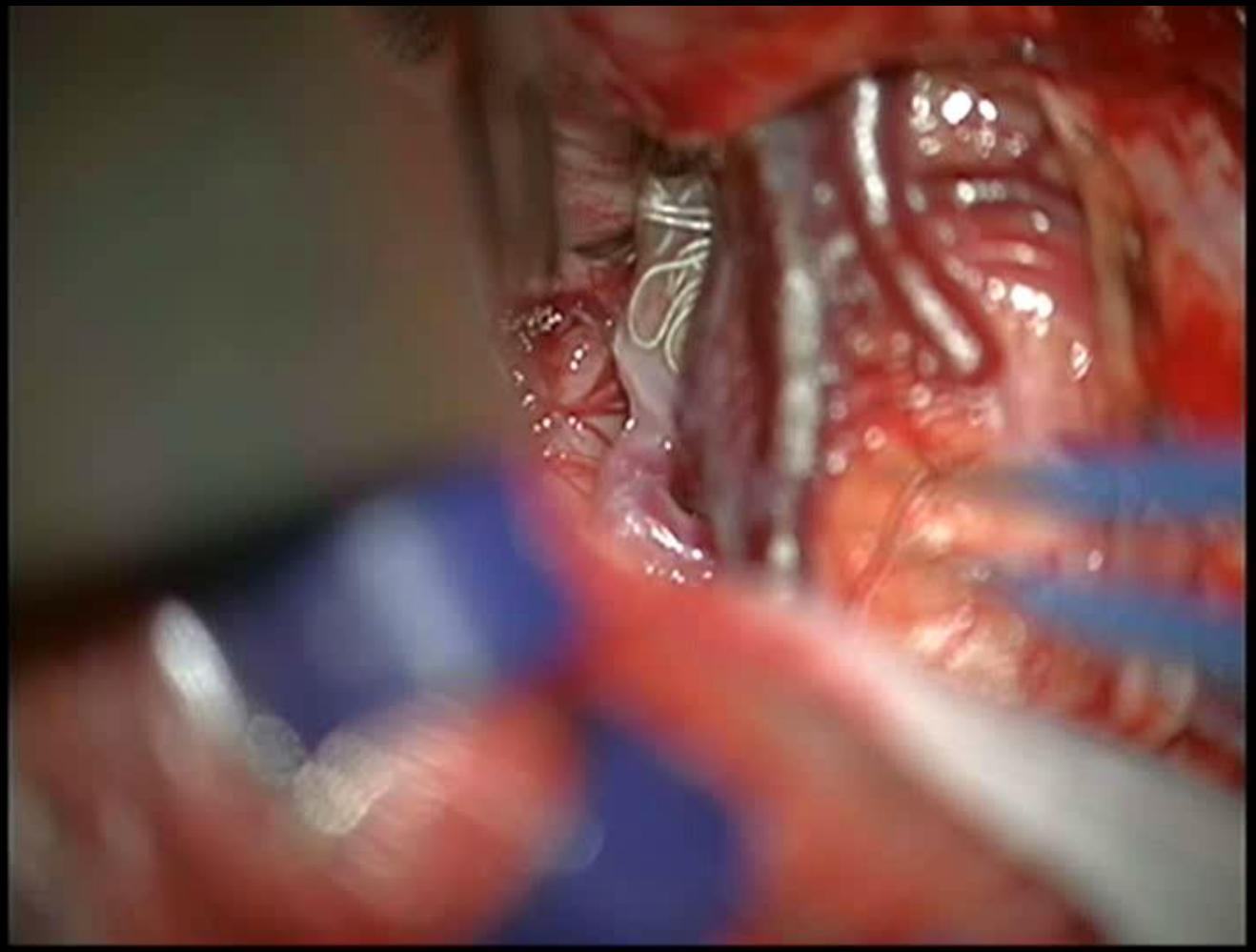
1.Small space on the neck for clip placement

2. Dome/Neck wall stiffness

3. Scar tissue around dome/neck and adhesion of coils to brain parenchima through dome wall

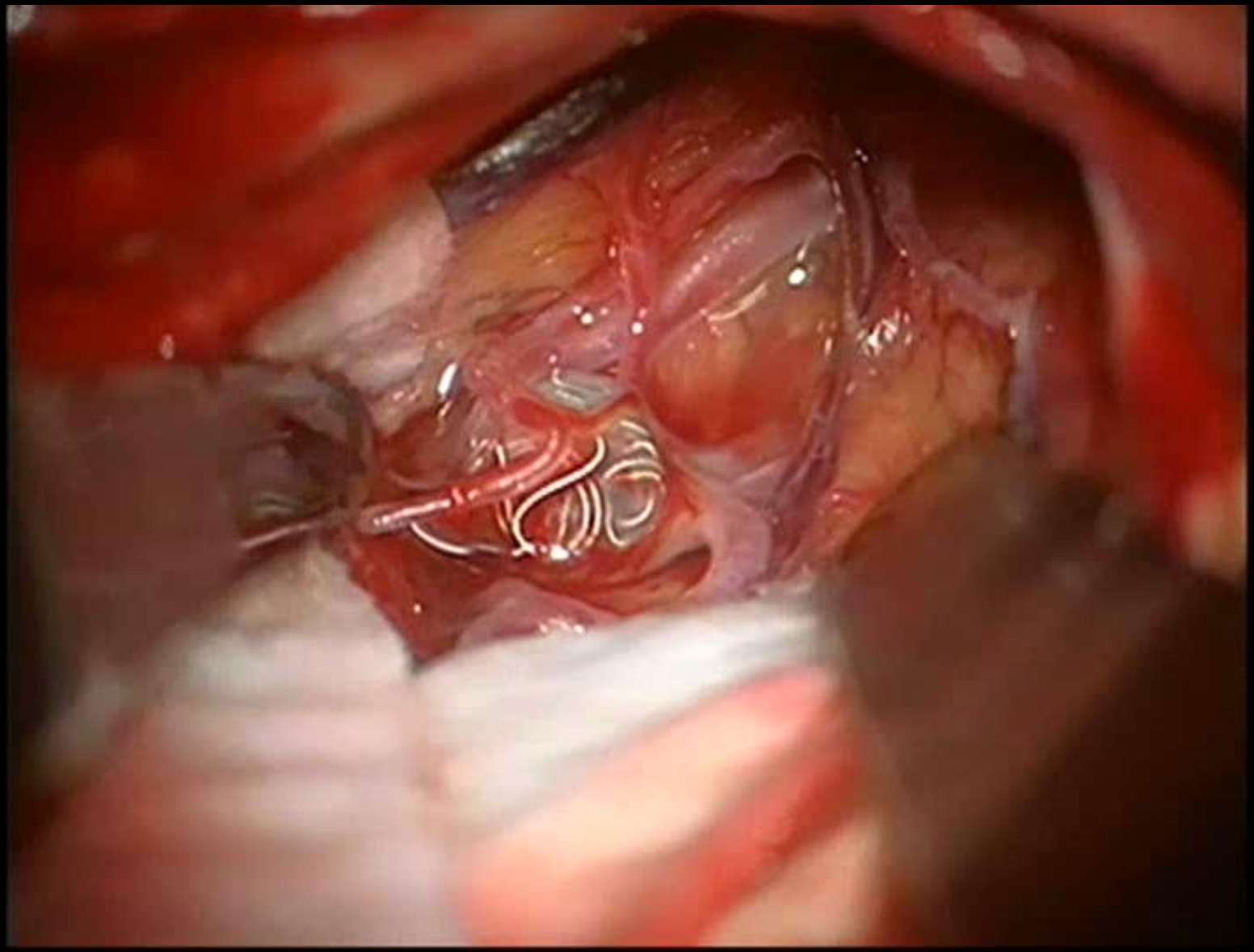
Video #6

Previously coiled aneurysm
(Right MCA bleeding aneurysm)



Video #7

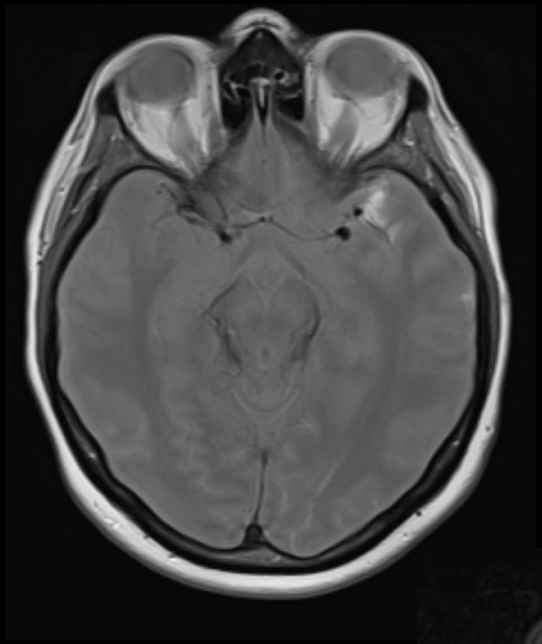
Previously coiled aneurysm
(Left MCA bleeding aneurysm)

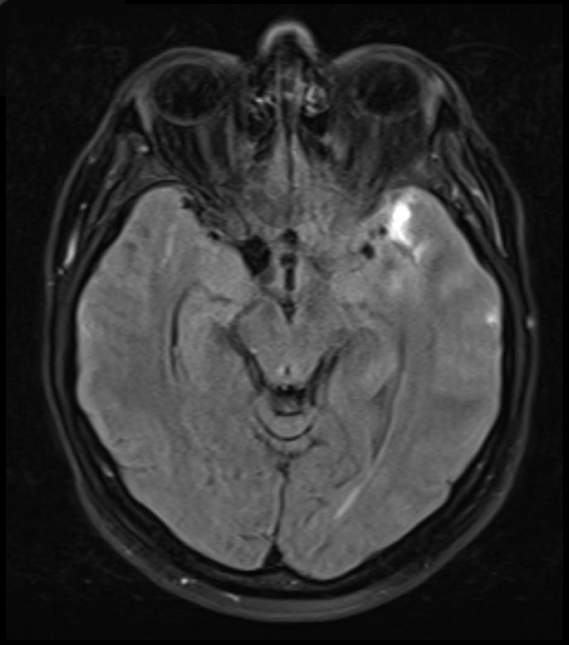


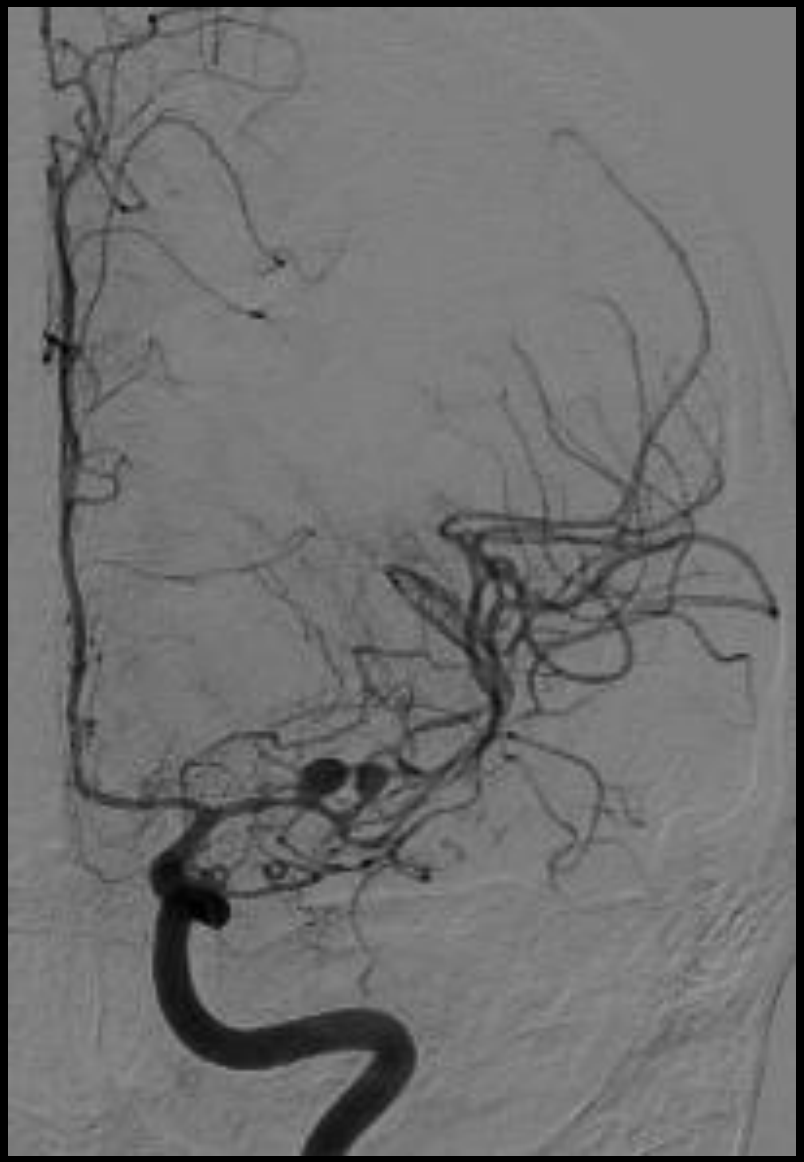
Monitoring in aneurysm surgery
Flow-assisted microsurgical clipping
Flowmetry in complex aneurysms
Is it enough?

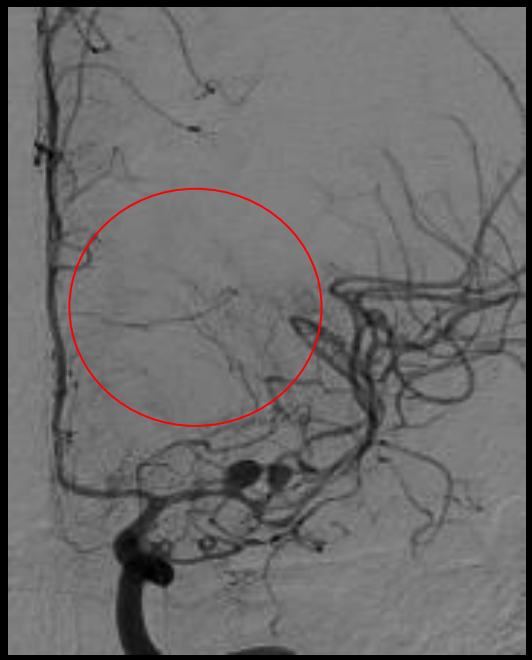
F/63Y SAH H&H:1
MCA bleeding bifurcation + M1 unruptured aneurysms

ICG-VA + flowmetry
No IOM









Strenghts and weaknesses of intraoperative tools

	Advantages	Main drawbacks
Flowmetry	Quantitative assessment Safe, fast, easy Time No large exposure Can be repeated	Perforating arteries not assessed Learning curve
Intra-op DSA	Artreries non exposed in the surgical field	Invasive, Time consuming Team and equipment Time Repeated assessment is difficult
Microvascular Doppler	Real time assessment	Qualitative assessment
ICG-VA	perforator patency?	Can only assess vessels directly visible through the operating microscope field, Calcifications. Clot. Time Qualitative assessment
IOM	High predictivity	Influenced by anesthetic technique, prone to false negatives

Strenghts and weaknesses of intraoperative tools

	Intraop DSA	Micro Doppler	Flowmetry	ICG	EPs
Incomplete clipping					
Dome remnant	++	(+)	-	++	-
Neck remnant	++	-	-	+	-
Branching vessel					
Stenosis	+	(+)	++	(+)	(+)
Occlusion	++	++	++	++	+
Perforator occlusion	(+)	(+)	-	+	++
Time and procedure risk	**Yes**	**No**	**No**	**No**	**No**

Raabe et al, J Neurosurg Sci 2016
(partially modified)

++ Very High + High (+) Low - Not applicable

Monitoring in aneurysm surgery
Flow-assisted microsurgical clipping
Flowmetry in complex aneurysms
Is it enough?
Neurophysiological monitoring and ICG

Our strategy – Neurophysiological monitoring

. *MEPs SSEPs monitoring*
. *Cortical vs Scalp electrodes*

Video #8

MEPs role in perforators occlusion detection (Right P-Comm unruptured aneurysm)

ICG-VideoAngiography (ICG-VA)

Indocyanine green (ICG) dye is a near-infrared fluorescent tricarbocyanine dye

The absorption and emission peaks of ICG dye are 805 and 835 nm, respectively

After ICG is intravenously injected, it binds almost completely to globulins, preferentially to α1-lipoproteins, within 1 to 2 seconds.

The normal vascular permeability is preserved, and the dye remains in the intravascular compartment.

The ICG dye is not metabolized in the body, and it is eliminated almost entirely via the liver.

The dye has a plasma half-life of 3 to 4 minutes

The recommended dose of ICG dye for videoangiography is 0.2 to 0.5 mg/kg, and the total daily dose should not exceed 5 mg/kg.

ICG-VideoAngiography (ICG-VA)

*First published data in 2003^*

*. 4-9% remnant detected^*

.7% detection of main artery occlusion °

. 3% detection of perforating artery occlusion °

.92-98% concordance with DSA ^

*Prospective study in 2005**

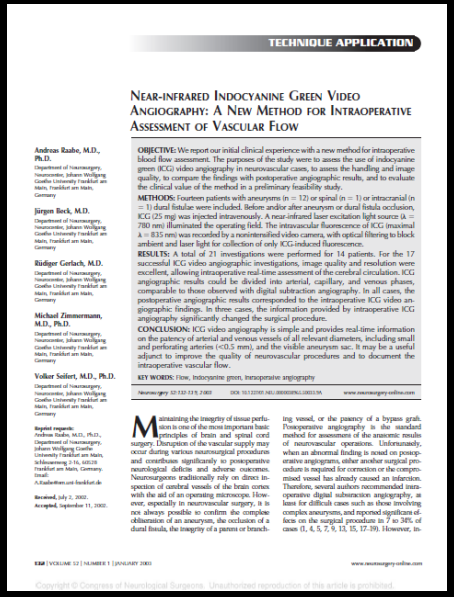
Intra-op ICG vs Post-op DSA

*. Suboptimal or wrong clip position in 8 of total 10%**

Recent data

*. ICG lead to wrong clipping in 5-10% ***

*. ICG cannot detect 3-7% additional findings showed by DSA***



TECHNIQUE APPLICATION

NEAR-INFRARED INDOCYANINE GREEN VIDEO ANGIOGRAPHY: A NEW METHOD FOR INTRAOPERATIVE ASSESSMENT OF VASCULAR FLOW

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Rüdiger Gerlach, M.D.
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OBJECTIVE: We report our initial clinical experience with a new method for intraoperative blood flow assessment. The purposes of the study were to assess the use of indocyanine green (ICG) video angiography in neurovascular cases, to assess the handling and image quality, to compare the findings with postoperative angiographic results, and to evaluate the clinical value of the method in a preliminary feasibility study.

METHODS: Fourteen patients with aneurysms (n = 12) or spinal (n = 1) or intracranial (n = 1) dural fistulae were included. Before and/or after aneurysm or dural fistula occlusion, ICG (25 mg) was injected intravenously. A near-infrared laser excitation light source (λ = 780 nm) illuminated the operating field. The intravascular fluorescence of ICG (maximal λ = 835 nm) was recorded by a noninterlaced video camera, with optical filtering to block ambient and laser light for collection of only ICG-induced fluorescences.

RESULTS: A total of 21 investigations were performed for 14 patients. For the 17 successful ICG video angiographic investigations, image quality and resolution were excellent, allowing intraoperative real-time assessment of the cerebral circulation. ICG angiographic results could be divided into arterial, capillary, and venous phases, comparable to those observed with digital subtraction angiography. In all cases, the postoperative angiographic results corresponded to the intraoperative ICG video angiographic findings. In three cases, the information provided by intraoperative ICG angiography significantly changed the surgical procedure.

CONCLUSION: ICG video angiography is simple and provides real-time information on the patency of arterial and venous vessels of all relevant diameters, including small and perforating arteries (<0.5 mm), and the visible aneurysm sac. It may be a useful adjunct to improve the quality of neurovascular procedures and to document the intraoperative vascular flow.

KEY WORDS: Flow, Indocyanine green, Intraoperative angiography

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Maintaining the integrity of tissue perfusion is one of the most important basic principles of brain and spinal cord surgery. Disruption of the vascular supply may occur during various neurosurgical procedures and contributes significantly to postoperative neurological deficits and adverse outcomes. Neurosurgeons traditionally rely on direct inspection of cerebral vessels of the brain cortex with the aid of an operating microscope. However, especially in neurovascular surgery, it is not always possible to confirm the complete obliteration of an aneurysm, the occlusion of a dural fistula, the integrity of a parent or branching vessel, or the patency of a bypass graft. Postoperative angiography is the standard method for assessment of the anatomic results of neurovascular operations. Unfortunately, when an abnormal finding is noted on postoperative angiograms, either another surgical procedure is required for correction or the compromised vessel has already caused an infarction. Therefore, several authors recommended intraoperative digital subtraction angiography, at least for difficult cases such as those involving complex aneurysms, and reported significant effects on the surgical procedure in 7 to 34% of cases (1, 4, 5, 7, 9, 13, 15, 17-19). However, in-

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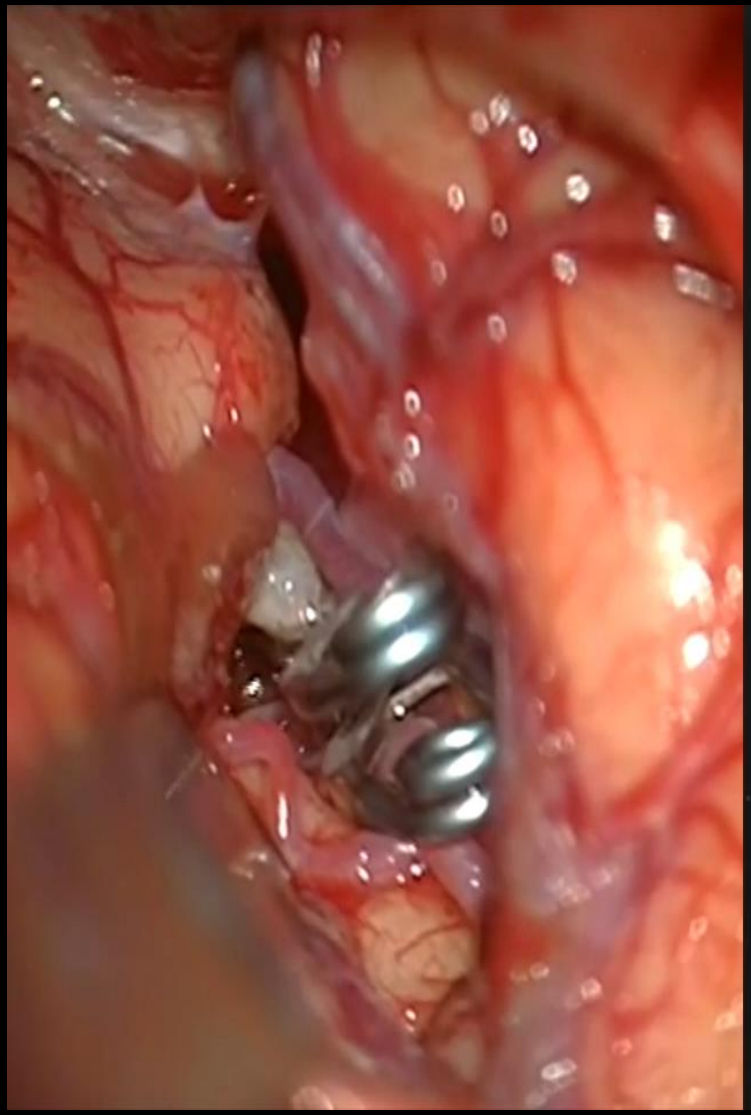
^ *Raabe et al, Neurosurg 2003*

° *De Oliveira et al, Neurosurg 2006*


Long Replay 1 / 5 - 00:10.2 / 01:07

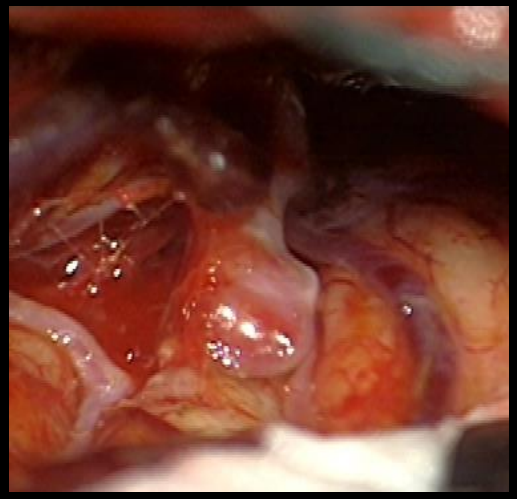
Video #9

Indocyanine Green Videoangiography (ICG-VA)
(Right MCA unruptured aneurysm)



Monitoring in aneurysm surgery
Flow-assisted microsurgical clipping
Is it enough?
Neurophysiological monitoring
Multimodal strategy

Aneurysm exposure → Flowmetry



↓

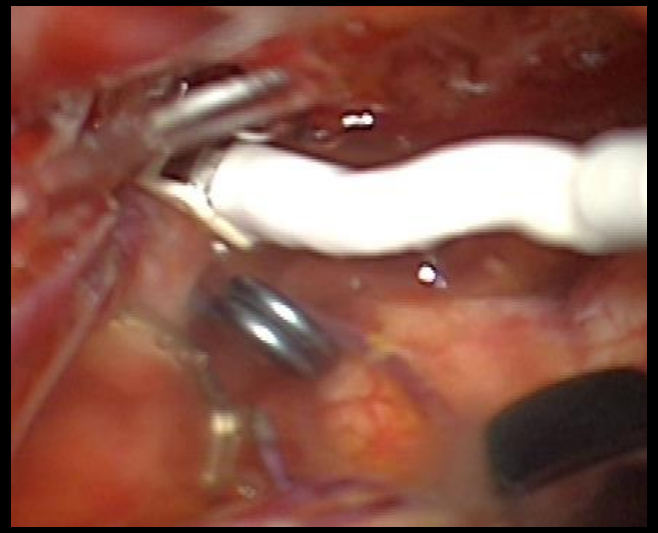
ICG-VA (optional)

↓

Clipping

↓

Flowmetry



Flow drop >25% → Clip repositioning

Flow drop <25% → ICG-VA (squeezing)

→ Clip repositioning

↓

Flowmetry

Flow drop >25% → Clip repositioning

Flow drop <25% → ICG-VA (squeezing)

ICG-VA (squeezing) → Complete exclusion

ICG-VA (squeezing) → Remnant → Clip repositioning

Complete exclusion → Sac opening/puncturing

Neurophysiological Monitoring

Microsurgical Clipping of Intracranial Aneurysms Assisted by Neurophysiological Monitoring, Microvascular Flow Probe, and ICG-VA: Outcomes and Intraoperative Data on a Multimodal Strategy

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85 pts/96 aneurysms

Flowmetry + EPs + ICG

Aims

. Strategy results
Remnant, Strokes (clip related)

. Impact on surgery
Clip repositioning

. Relationship CR/Aneurysm features (Atheroma, Location, Size)

Table 1. Patients and Aneurysms

Clinical Case Features	n (%)
Total number of aneurysms	96
Presentation	
Ruptured aneurysms	46 (47.9%)
Unrupted aneurysms	50 (52.1%)
Sex	
Male	28 (29.2%)
Female	57 (59.4%)
Neck-dome Atheroma	
Yes	26 (27.1%)
No	70 (72.9%)
Size	
<7 mm 11	37 (38.5%)
7–12 mm 18	46 (48.0%)
13–24 mm	13 (13.5%)
Aneurysm location	
Proximal group	45 (46.9%)
A1 segment	1 (1%)
Anterior communicating complex	16 (16.7%)
M1 segment	1 (1%)
ICA-posterior communicating	15 (15.6%)
ICA bifurcation	8 (8.3%)
ICA-anterior choroidal	2 (2.1%)
ICA-ophthalmic	2 (2.1%)
Distal group	51 (53.1%)
Pericallosal	2 (2.1%)
MCA bifurcation	49 (51%)

ICA, internal carotid artery; MCA, middle cerebral artery.

Strategy results

Aneurysm remnant 1.1%

Clip-related strokes 10.4%

Symptomatic 2.08%

Asymptomatic 8.32%

Table 2. Patients with Postoperative Stroke

		Causes of Clip Repositioning						
Patient Number	SAH	EPs	Flowmetry	ICG-VA	Ischemic Territory	Postoperative Deficits	Aneurysm Location	Atheroma
1	Yes	–	–	–	Hypotalamic	—	Bleeding ACoA + MCA bif	No
2	No	–	–	–	Fronto-orbitary	—	ACoA + MCA bif	No
3	No	–	+	–	Frontal M2	Motor	MCA bif	Yes
4	Yes	–	+	–	Frontal M2	Language	MCA bif	Yes
5	Yes	–	+	–	Frontal M2	—	MCA bif	No
6	No	–	+	–	Basal ganglia	—	M1	No
7	Yes	+	–	–	Basal ganglia	—	P-comm	No
8	Yes	–	–	–	Hypotalamic	—	ACoA	No
9	Yes	–	–	–	Hypotalamic	—	ACoA	No
10	Yes	–	–	–	Hypotalamic	—	P-comm	No

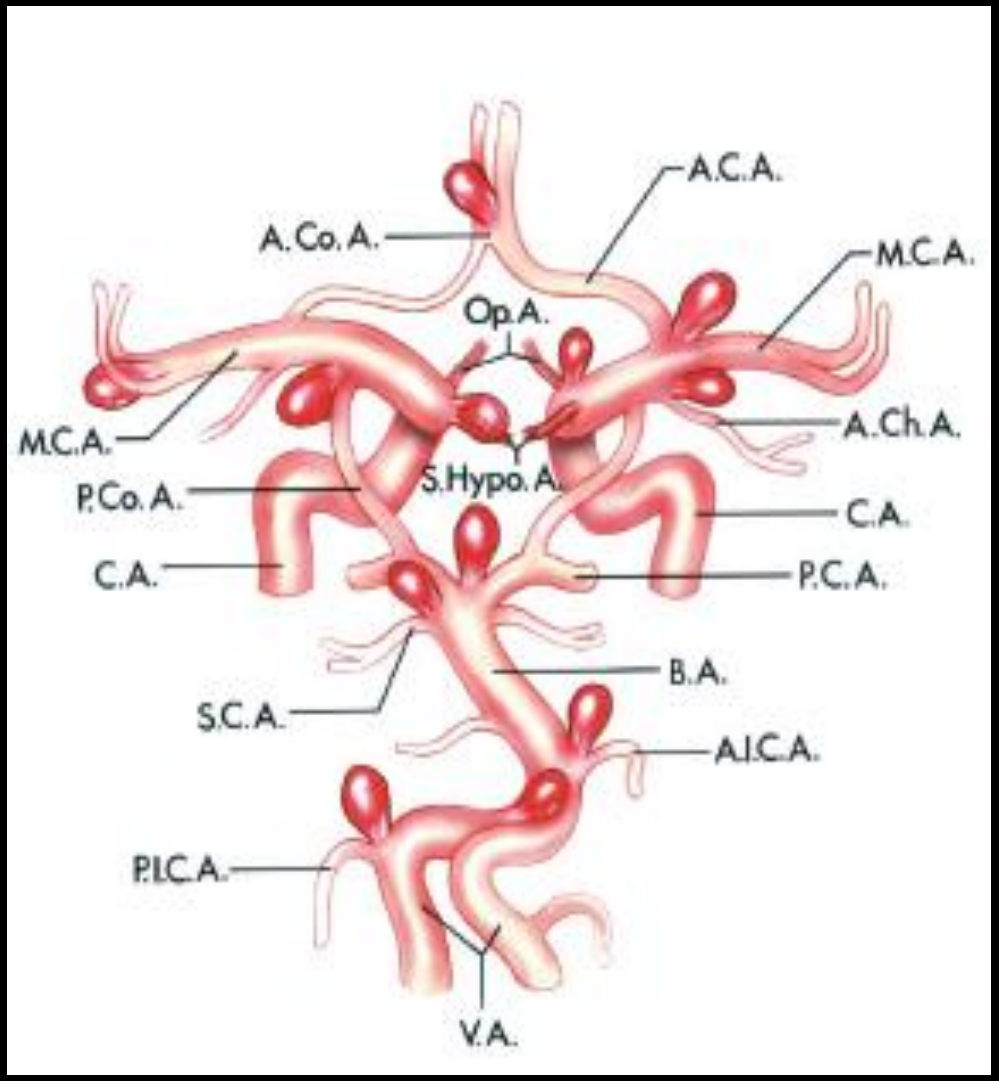
SAH, subarachnoid hemorrhage; EP, evoked potentials; ICG-VA, indocyanine green video angiography; ACoA, anterior communicating artery; MCA, middle cerebral artery; ICA bif, internal carotid artery bifurcation; P-comm, posterior communicating artery.

Clip repositioning rate 40.6%

MEP	9.3%
Flowmetry	22.91%
ICG-VA	8.3%
ICG	1.05%
Squeezing	7.25%

Monitoring technique depending on aneurysm feature

	Location		Atheroma
	Proximal	Distal	
MEP	$p<0.05$	-	-
Flowmetry	-	$p< 0.01$	$p< 0.01$
ICG-VA	-	-	$p<0.05$



A Tailored strategy?

. Atheroma → Flowmetry, ICG

. Distal (MCA and pericallosal) → Flowmetry

. Perforators → EPs

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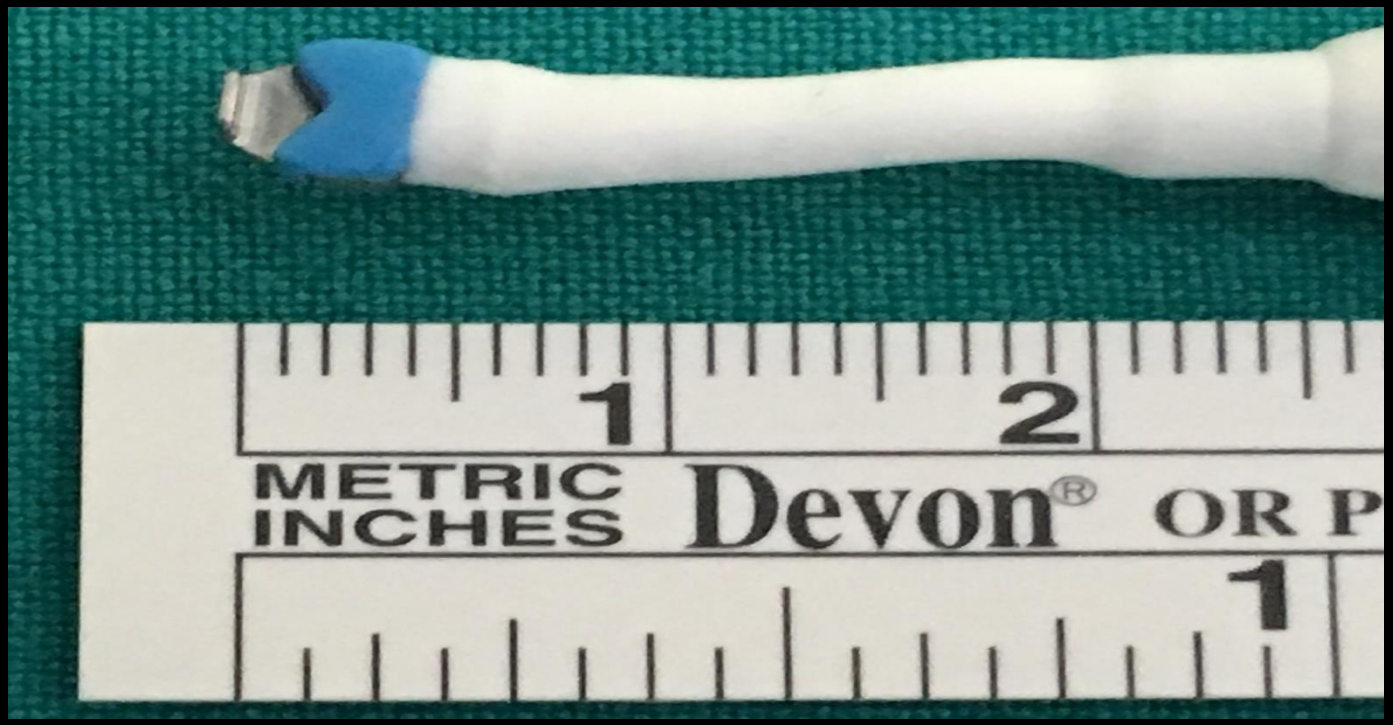
New perspectives about flowmetry


1
2
METRIC
INCHES
Devon®
OR P
1

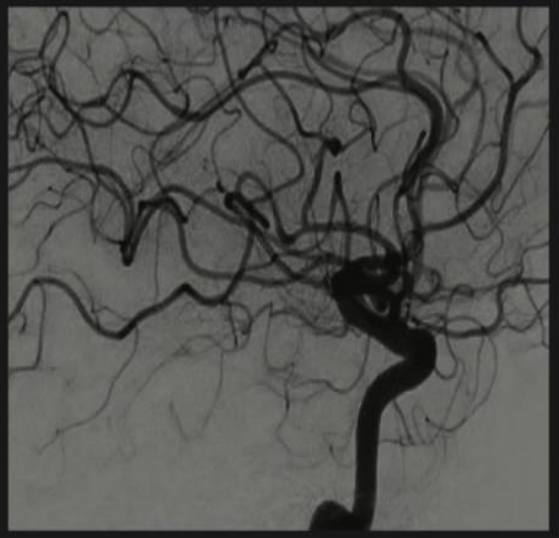
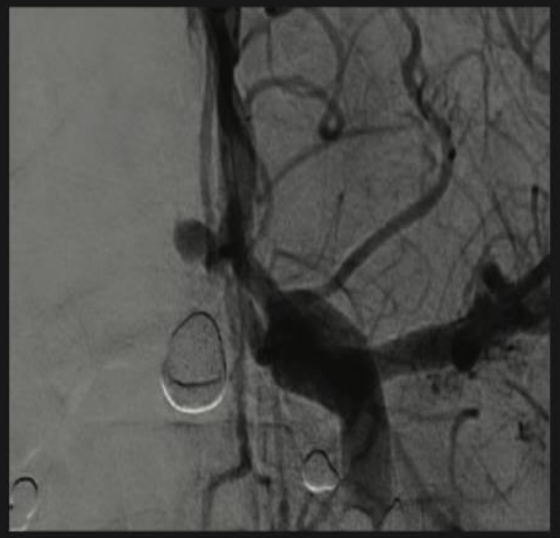

transonic
Microvascular Flow
1.0mm
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
METRIC
INCHES
Devon®
OR Products & Safety Solutions
Measurement device is not calibrated. Use for approx. measurement only.
MADE IN U.S.A.
1 2 3 4 5 6

Video #10

Small M2 flow evaluation with microprobe (Right MCA unruptured aneurysm)

Video #11

Heubner Artery flow evaluation with microprobe (ACoA unruptured aneurysm)

Video #12

P -Comm flow evaluation with microprobe (P-Comm unruptured aneurysm)

Final Considerations

. Neurological outcome and quality of life represent primary aims of modern cerebrovascular surgery

. Intra-operative technologies can reduce post-operative stroke occurrence

. Flowmetry has a crucial role in reducing post-operative stroke due to main branches occlusion

. Best monitoring technique can depend on aneurysm features

. A "tailored monitoring strategy" can be pursued