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Procedural Paradigm in Intraoperative Aneurysm Clipping with Microdoppler Ultrasound, Near-Infrared Indocyanine Green Videoangiography and Intraoperative Angiography

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Abstract

Introduction: The aim of surgical treatment of aneurysm is complete aneurysm obliteration and maintenance of a physiologic flow in the proximal and distal vessels. To avoid any risks of failing these aims intraoperative-angiography was introduced in neurosurgery first, followed by microdoppler-ultrasonography and lately with Indocyanine-Green-Videoangiography (ICG-VA). After reviewing the literature and analysing our own results with the different methods we propose an intraoperative paradigm to optimize aneurysm clipping with the least risk of vessel occlusion or residual aneurysm.

Patients and methods: Twenty-five incidental aneurysms (bleeding aneurysms were excluded) were clipped in 2012 in our hospital with intraoperative use of microdoppler and ICG-VA. All patients received postoperative cerebral angiography. The surgical results with use of these methods were compared to postoperative angiography. Review of literature has been performed and a procedural flow chart was created.

Results: In 20/25 (80%) patients the combination of microdoppler and ICG-VA led to an optimisation and repositioning of the clip intraoperatively. In the remaining 5 patients clip re-positioning was not necessary since optimal position was confirmed. Reasons for clip re-positioning were stenosis of the vessels related to the aneurysm or a residual aneurysm neck. None of the patients needed another surgery according to postsurgical angiography. Review of the literature implicates a complemental role for microdoppler, ICG-VA and intraoperative-angiography since every method has its own advantages and disadvantages. We propose a flow chart for the use of all three methods together.

Conclusion: Microdoppler, ICG-VA and intraoperative-angiography should be used in concert under special circumstances. Using them in a given order according to their simplicity, speed and cost effectiveness may reduce complications related to the microsurgical clip placement for intracranial aneurysms. However, prospective studies are needed to prove our observations.

Keywords: Intraoperative cerebral angiography; Microdoppler ultrasonography; Indocyanine green videoangiography; Aneurysm clipping; Vessel occlusion; Residual aneurysm

Introduction

Aneurysm clipping aims towards optimal obliteration of an aneurysm without narrowing or occluding the parental of branching vessels. In the beginning of aneurysm clipping postsurgical angiography was the only method to prove optimal clip position. Unfortunately postsurgical angiography showed what went wrong during surgery in retrospect. Vessel occlusions inevitably led to infarction of brain tissue without a chance of correcting the failure. Residual aneurysm or even unclipped aneurysms led to re-operation of patients. A failure rate of about 12% could be seen in post-surgical angiography even in the hands of the most experienced surgeons [1]. By assumption it is clear that less experienced surgeons had a much bigger failure rate. To improve the rate of complete aneurysm obliteration and avoid vessel occlusion, intraoperative angiography was introduced to the field and showed that in about 12% - 27% of surgeries aneurysm clips had to be repositioned [2-5]. Further intraoperative optimisation of clip positioning with microdoppler ultrasonography and in the last decade with ICG-VA [6] came to reduce the complication rate significantly. After surgery postoperative angiography for evaluation of complete aneurysm obliteration even with the use of intraoperative ICG and microdopller remains the gold standard. Recently we have shown in animal experiments that the application of microdoppler and videoangiography after suturing of thin vessels to create stenosis, provide different informations which can enhance the analysis of the current situation especially in a combination of both [7].

In the present study we analyze the pros and cons of every different method and propose an operational paradigm to optimize the combined use of intraoperative microdoppler, ICG-VA and intraoperative as well as postsurgical angiography in aneurysm clipping. The Barrow Ruptured Aneurysm Trial shows that clipping is still an effective and important way to treat aneurysm. There are no differences in long term outcome measurement (3 years) in the direct

comparison to coil embolisation [8]. That is one of the reasons why it is still important to investigate different terms for optimisation of surgical treatment and outcome for aneurysm-clipping.

Patients and Methods

Twenty five patients were operated in the last 12 months in our department on incidental aneurysms with the combined use of microdoppler and ICG-VA. An OPMI Pentero microscope, which recorded the ICG-VA has been used. All aneurysms where on the anterior circulation and operated through a pterional approach. The whole surgery and the ICG-VA were recorded. The microdoppler results were noticed by the first author who operated the patients together with the senior author. All the results were compared to the postsurgical angiography results.

Pubmed review of the literature was performed searching the terms, "intraoperative angiography", "microdoppler ultrasonography", "aneurysm clipping", "indocyanine green videoangiography" and "cerebral angiography".

Results

In 20/25 (80%) patients the clip was re-positioned after change of the flow profile of the branching arteries either in ICG or microdoppler analysis (delayed filling of vessels in ICG or high pitched microdoppler sound). In 2 of the 20 (10%) patients (with clip repositioning) in which microdoppler showed a good clipping, ICG-VA showed the existence of a residual aneurysm neck forcing us to reposition the clip. In 2 of 20 patients (10%) ICG-VA failed to show any pathology, microdoppler ultrasonography showed stenosis of the branching vessels and a clip repositioning had to be performed. In post-surgical angiography excellent results could be verified in 100%, accordance to the combined results of microdoppler and ICG-VA. The use of microdoppler and ICG-VA complement each other and are valuable in optimising the position of the aneurysm clip. By the use of only one method (irrespective which one), we would fail 8% of optimal clip positioning.

Table 1 shows the advantages and disadvantages of the use of intraoperative microdoppler and ICG-VA, which has been used in our department and in the literature, as well as the intraoperative angiography, which has been used and reported in other departments. Table 2 shows the aneurysm characteristics.

Figure 1 shows which method is ideal for every given circumstance (figure 1 A-1C). A residual aneurysm neck is best identified with intraoperative angiography and ICG-VA, but not with microdoppler (Figure 1A). Perforating arteries (up to 0.5 - 1 mm diameter) can be identified with angiography and ICG-VA, but for microdoppler-sonography it is difficult to identify those perforating arteries (Figure 1B).

	Microdoppler	ICG-VA	Intraoperative angiography
Time	Seconds	2 minutes	20 minutes
Visualisation field	Microscopes field	Extended microscope field	Brain hemisphere
Identifying stenosis	Good	Limited	Excellent
Residual aneurysm neck	Limited	Good	Excellent
Systemic adverse effects	None	Tachycardia, hypotension, skin erruptions (0.05-0.2%)	Contrast enhancement allergy, hypotension, tachycardia, cardiopulmonary decompensation (0.4-2.6%)
Disadvantages	Operator dependend	Limited visual field,	Expensive, use of ionizing radiation, not everywhere available, additional staff needed atheromatous vessels and large aneurysms limit the field

Table 1: Advantages and disadvantages of the microdoppler, ICG-VA and intraoperative angiography

A stenosis of the parent vessel can be identified by microdoppler and angiography, but less efficient by ICG-VA (Figure 1C). The stenosis caused by a clip can be identified by microdoppler when the operator is familiar and experienced with the method.

Figure 2 presents a flow chart on when to use every single method. Postsurgical angiography remains gold standard, since even after the use of all three methods together there is a rate of 1.9 % of stenotic distal branching arteries and a risk of 3.2 % of residual aneurysm [3].

The intraoperative movies are examples of the clipping accuracy with the use of ICG (Figure 3).

The clinical outcome of the patients was good. Three patients had a transient postoperative aphasia and one patient a paresis of the right hand. However, the symptoms declined gradually and all patients were discharged without neurological impairments. In the postoperative CT scans local ischemia accompanied with slight edema was present in two cases, but without association to the neurological condition of the patients. We assumed that these findings were probably associated to the opening of the Sylvian fissure, rather to clip repositioning.

Discussion

None of the three intraoperative methods is sufficient enough to stay on its own. Every method has its pros and cons and it is more than obvious that everyone complements the other. It is not a simple thought to use all three methods during a surgical clipping just by intuition. Especially for the less experienced surgeons there should be given a clear algorithm on how and when to use the different methods during aneurysm surgery. Simplicity, speed and cost effectiveness are important factors, which are considered in the creation of the proposed flow chart.

Macdonald et al, [1] showed that in a series of 66 patients, postoperative angiography showed residual aneurysm in 4%, unclipped aneurysms in 4% and 12% of major vessel occlusion. The need of intraoperative clipping control was obvious. In another study

with introduction of intraoperative angiography the benefit of the method was 12%-27% indicating the value of intraoperative angiography [2,4]. A number of studies justified the use of intraoperative angiography especially in ruptured aneurysms [3], as well as in giant and large aneurysms [4,5,9]. The location of aneurysms as an indication for the intraoperative angiography use was inconclusive since different studies favoured different locations. Even with the use of intraoperative angiography, postsurgical angiography remains gold standard since in 1.9% of cases distal branch occlusion was seen and in 3.2% residual aneurysms could be identified in postsurgical angiography, which was overseen in the intraoperative angiogram [4]. The intraoperative angiography for example in a hybrid neuro-interventional suite can also be used for other cerebral vessel-pathologies for example arterio-venous malformations [10].

Even that intraoperative angiography showed excellent results in optimizing clip application and reducing the risk of residual aneurysm and vessel stenosis the method has also disadvantages. The mean time needed to draw conclusions is about 20 minutes. In case of vessel occlusion 20 minutes could be enough to lead to brain infarction and clip correction was too late in 33% of cases [11,12]. Additionally, the use of the contrast enhancement agent could lead to adverse effects like hypotension and even death through cardiopulmonary decompensation. The adverse effect risk is very low though (0.7% and only one death in about 90.000 administrations) [13] and can be taken out of consideration. The need of additional staff for use of the intraoperative angiography and the costs however, are factors which limit the use of intraoperative angiography as is the application of ionizing radiation. To overcome the limitations of intraoperative angiography neurosurgical centres use the intraoperative microdoppler. The microdoppler is accurate and conclusions can be drawn into seconds. It is proven that the microdoppler is safe, accurate and is a low cost imaging modality [14]. However, the accuracy is operator dependent and therefore participation in microdoppler courses is crucial. Especially the insonation of small perforating vessels may be difficult and unreliable [6,11]. To overcome the obstacles of microdoppler sonography ICG-VA was introduced to the cerebrovascular field. It was first used by ophthalmologists to illuminate retinal blood flow using the fluorescent dye fluorescein. Feindel et al., 1967 [15] was the first who applied fluorescence angiography for intraoperative visualisation of cerebral vessels [15]. The method was not popularized though until 2003 when Raabe et al., 2003 introduced the fluorescence with indocyanine green integrated in a microscope with modern video technology enabling the surgeon to visualize the cerebral vessels through the microscope [6]. The speed of the method compared to intraoperative angiography is highly increased. It takes only 2 minutes after ICG application to draw conclusions and readjust a clip [16]. An additional advantage of ICG-VA compared to microdoppler sonography is that even small perforators with a diameter of less than 1 mm can be easily visualized [6,11]. Limitations of this method are that the anatomy outside the microscope´s view is not possible to be seen compared to intraoperative angiography which shows the vascularisation of a whole hemisphere [11]. Vessels covered by the aneurysm or by brain tissue cannot be observed by ICG-VA [6,16,17]. Atheromatous vessel walls or thrombosed aneurysms obliterate ICG-VA view too [16].

Patient	Location	Shape	Size
1	MCA	Sacullar	<1 cm
2	MCA	Sacullar	<1 cm
3	MCA	Sacullar	<1 cm
4	MCA	Sacullar	<1 cm
5	MCA	Sacullar	<1 cm
6	MCA	Sacullar	<1 cm
7	MCA	Sacullar	1.5 cm
8	MCA	Sacullar	<1 cm
9	MCA	Sacullar	<1 cm
10	MCA	Sacullar	<1 cm
11	MCA	Sacullar	<1 cm
12	MCA	Sacullar	<1 cm
13	MCA	Sacullar	<1 cm
14	MCA	Sacullar	<1 cm
15	MCA	Sacullar	<1 cm
16	MCA	bilobar	<1 cm
17	MCA	bilobar	<1 cm
18	MCA	Fusiform, calcified	2.1 cm

19	MCA	Saccular, calcifications	2 cm
20	MCA	Sacullar, calcifications	1.5 cm
21	Basilar	sacullar	1.5 cm
22	AComA	sacullar	<1 cm
23	AComA	multilobar	<1 cm
24	Pericallosa	bilobar	<1 cm
25	Pericallosa	sacullar	<1 cm

Table 2: Characteristics of the aneurysms operated in our departement in the year 2012-2013 in which ICG und Doppler have been used.

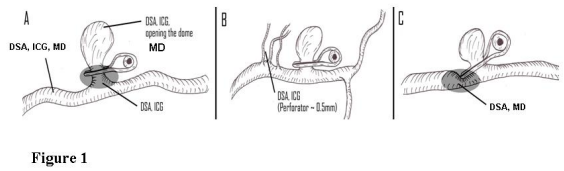

Figure 1

Figure 1: Advantages and disadvantages of microdoppler, ICG-VA and angiography. A. The aneurysm neck can be best seen by ICG-VA and angiography. The microdoppler is not accurate enough for identifying a residual neck. Opening the dome allows a control of aneurysm literation.B. Perforators of a diameter of 0.5 – 1 mm can be visualized by ICG-VA and angiography but not by microdoppler. C. A stenotic vessel after clipping can by identified better with microdoppler and angiography and less accurate by ICG-VA ICG: indocyanine green videoangiography, DSA: angiography, MD: Microdoppler

In 2 cases ICG-VA showed completely occlusion of the aneurysm but incision of the aneurysm dome showed slow but significant dye extravasation indicating a failure of ICG-VA [18]. The reason of ICG-VA failure was that the aneurysm in the first case had a wide neck and was difficult to visualize by ICG-VA and in the second case there was an atheroma in the neck, which did not allow complete aneurysm closure [18]. Microdoppler of the aneurysm after clipping to show any intra-aneurysmal flow can be a step before opening the aneurysm since flow in the aneurysm would prove that the aneurysm is not completely obliterared. The benefit of ICG-VA was given as 26% in one study with a misleading rate of 2% [19]. The simplicity of the method is also of great advantage [20]. The adverse effect rate with hypotension, tachycardia, skin eruptions is given as 0.05 – 0.2% [13,21].

Mücke et al. shows in 2010 by a rat model that the microdoppler as well as the ICG-VA are quick and reliable methods with high sensitivity and specificity for assessing blood flow in vessels intraoperatevely [22-24].

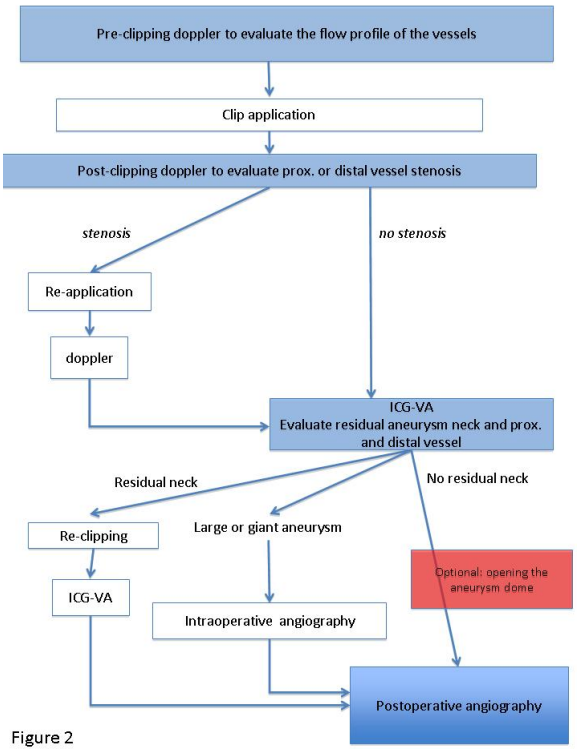

Figure 2

Figure 2: Operational paradigm for the combined use of microdoppler, ICG-VA and intraoperative angiography. Flow chart showing the proposed used of all three methods in concert to gain the best possible information. Consideration of simplicity, speed, accuracy, cost and need of additional staff.

Conclusion

Our results allow the assumption that the combined use of microdoppler and ICG-VA may lead to confirmation of optimal clip placement. Hence, the use of intraoperative angiography may be

reserved for the evaluation of complex, large and giant intracranial aneurysms. We propose an intraoperative plan for applying these methods in concert. After surgery, post-operative angiography should remain the gold standard since a small rate of residual aneurysms and arterial stenosis can be overseen, even by combination of all three intraoperative methods together.

However, at this point we underline that our study has also limitations. The major point is its retrospective character. Larger prospective studies are needed to prove and to confirm our observations.

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