Arq Neuropsiquiatr 2005;63(2-A):339-344

CLIP READJUSTMENT IN ANEURYSM SURGERY AFTER FLOW EVALUATION USING THE ULTRASONIC PERIVASCULAR PROBE

Case report

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ABSTRACT - Occlusion or stenosis of a parent vessel or its distal branches is a major cause of poor patient outcome after cerebral aneurysm surgery. Despite great attempts to preserve patency at the time of clip application, intraoperative visual observation may not reveal arterial compromise or occlusion. Quantitative measurement of blood flow in cerebral vessels during aneurysm surgery can help prevent ischaemia and improve patient outcome. We report a case of a large complex middle cerebral artery (MCA) aneurysm in which perivascular microflow probes were used to measure blood flow quantitatively in MCA and its branches before and after aneurysm clipping. Following aneurysm clipping, blood flow in the MCA branches were significantly reduced to less than its initial baseline value with occlusion of the inferior M2 segment. Prompt detection of compromised blood flow gave the surgeon the opportunity to adjust the clip. This adjustment was performed several times until restore MCA flow to its preclipping values. Intraoperative quantitative vessel-flow measurements were safe and may have prevented cerebral ischaemia and neurological deficit to this patient.

KEY WORDS: ultrasonic perivascular transit-time flow probe, aneurysm surgery, middle cerebral artery.

Reajuste do clipe na cirurgia de aneurisma após avaliação do fluxo arterial por meio de micro-sonda ultrasônica perivascular: relato de caso

RESUMO - A medida quantitativa do fluxo sanguíneo nos vasos cerebrais durante a cirurgia de aneurisma pode ajudar na prevenção de eventos isquêmicos e, portanto, melhorar os resultados. Relatamos o caso de paciente portador de aneurisma grande e complexo da bifurcação da artéria de cerebral média (ACM), no qual foram usadas micro-sondas ultrasônicas perivasculares para medir o fluxo de sangue quantitativamente na ACM e nos seus ramos antes e depois da clipagem do aneurisma. Após a clipagem do aneurisma, o fluxo de sangue diminuiu em todos os ramos, fazendo-se necessário o reajuste do clipe. Após vários ajustes na posição do clipe, o fluxo sanguíneo nos segmentos da ACM foi restabelecido. A descoberta imediata da alteração do fluxo de sangue proporcionou a oportunidade ao cirurgião de ajuste do clipe e conseqüentemente o restabelecimento do fluxo a valores compatíveis àqueles antes da clipagem. O uso de micro-sondas ultrasônicas perivasculares para medida do fluxo sanguíneo durante a cirurgia de aneurisma pode prevenir eventos isquêmicos e eventualmente déficits neurológicos.

PALAVRAS-CHAVE: micro-sonda ultrasônica perivascular, fluxo sanguíneo, aneurisma, artéria cerebral média.

The outcome of surgical treatment of cerebral aneurysms may be severely impaired by local ischaemia, or by infarction resulting from the inadvertent occlusion or stenosis of a parent vessel or its distal branches[1-4]. Incomplete aneurym occlusion, on the other hand, increases the risk of haemorrhage. Despite great attempts to preserve patency at the time of clip application, intraoperative visual observation may not reveal arterial compromise or occlusion[1].

Angiographic data provided in the literature indicate that an intraoperative method of measuring cerebral vessel flow during aneurysm surgery would enable early detection of compromised flow and may reduce the risk of permanent neurological deficit[5-7].

In this report we describe the use of a ultrasonic perivascular microflow probe for quantitative vessel-flow measurement during middle cerebral artery (MCA) bifurcation aneurysm surgery. This technique

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Received 21 June 2004, received in final form 19 September 2004. Accepted 10 November 2004.

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Fig 1. Computed tomography scan demostrating a subarachnoid hemorrhage grade IV in the right sylvian fissure and left ventricular cateter (A). Oblique right ICA angiogram revealing a large right MCA bifurcation aneurysm (B).

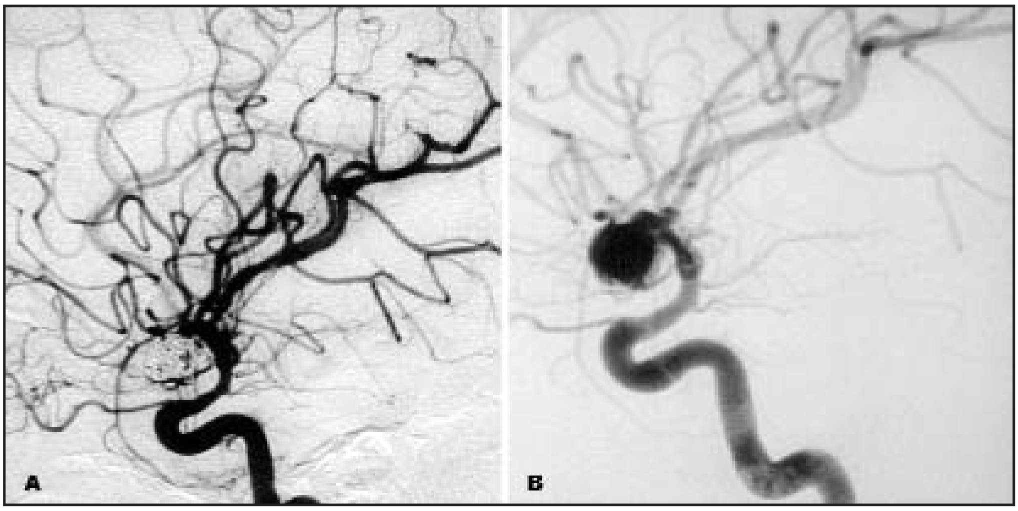


Fig 2. Lateral right ICA angiogram performed immediatly after embolization demonstrating apparent complete occlusion of the aneurysm (A), two weeks later demonstrating a partial recanalization of the posterior chamber of the MCA aneurysm (B).

permits immediate evaluating of vessel-flow during aneurysm clipping and the ability to repeated measurements if multiple clip adjustments are needed.

CASE

A 42-year-old right handed Caucasian man presented with headache, nausea and seizures. Two days prior to admission, the headache worsened. A computed tomography (CT) scan study demonstrated a subarachnoid hemorrhage in the right sylvian cistern, grade IV of Fisher (Fig 1A). In addition, there was an intraparenchymal hemorrhage involving the right temporal lobe. The patient was transferred to the University of Illinois at Chicago Medical Center for further evaluation and management.

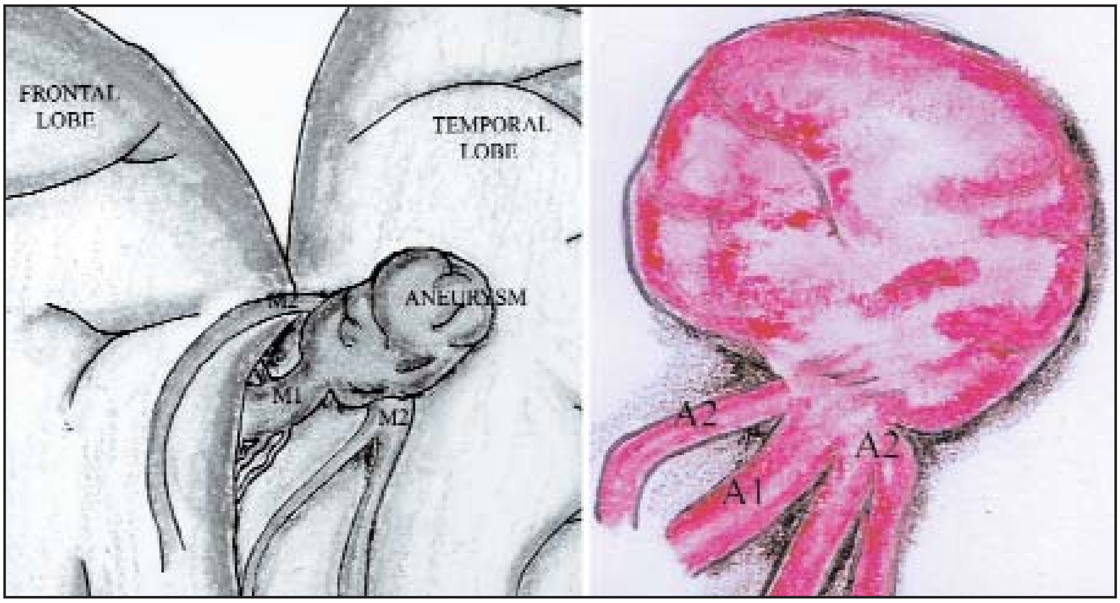


Fig 3. Schematic diagram showing a MCA aneurysm and two branches arising from the bifurcation of MCA with one branch very close to the neck of the aneurysm.

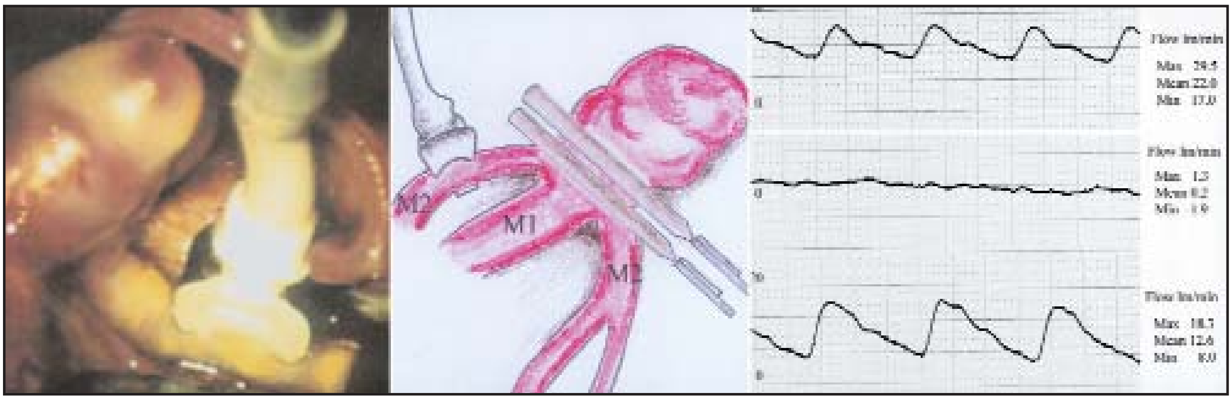


Fig 4. Schematic diagram showing flow probe on the M2 segment (A) and intraoperative tracings before (superior trace) and after (middle trace) clipping, and the final (inferior trace) mean blood flow (ml/min) after multiple clip readjustment (B).

Cerebral angiography revealed a large right MCA bifurcation aneurysm measuring 15 X 8 mm (Fig 1B). The aneurysm was thought to be sucessfully coiled (Fig 2A). Subsequent cerebral angiography revealed partial recanalization of the posterior chamber of the aneurysm (Fig 2B) and moderate vasospasm involving the right carotid artery and M1 segment of the right MCA.

The patient was surgically treated four weeks after coil embolization for aneurysm clipping. The aneurysm was approached through a right side pterional craniotomy. The aneurysm was found to be large and partially packed with coils and thrombus. The MCA was identified as its two branches (here referred as M1 and superior and inferior M2 segments) arising from its bifurcation, with one branch very close to the neck of the aneurysm (Fig 3). Once all branches arising from the bifurcation of MCA were dissected free, a cerebral protection was performed, and a temporarily clip was applied to the MCA and to the two other branches. The aneurysm was then completely dissected and an incision was made on the surface and the coils and thrombus were carefully removed from the aneurysm. Once the aneurysm coils were delivered, the lumen of the aneurysm was flushed with saline solution.

Intraoperative vessel-flow measurements were made using a perivascular microflow probe and mean flow readings were continuously displayed in millimeters per minute on the flowmeter console (Model HT300 Series; Transonic Systems, Ithaca, NY, USA). Prior to temporarily clipping, flow within the three segments of MCA was all measured. Baseline flows in the M1, superior M2 and inferior M2 segments were 26.7, 32.4 and 22.8 ml/minute, respectively (Table). The aneurysm was then reconstruct-

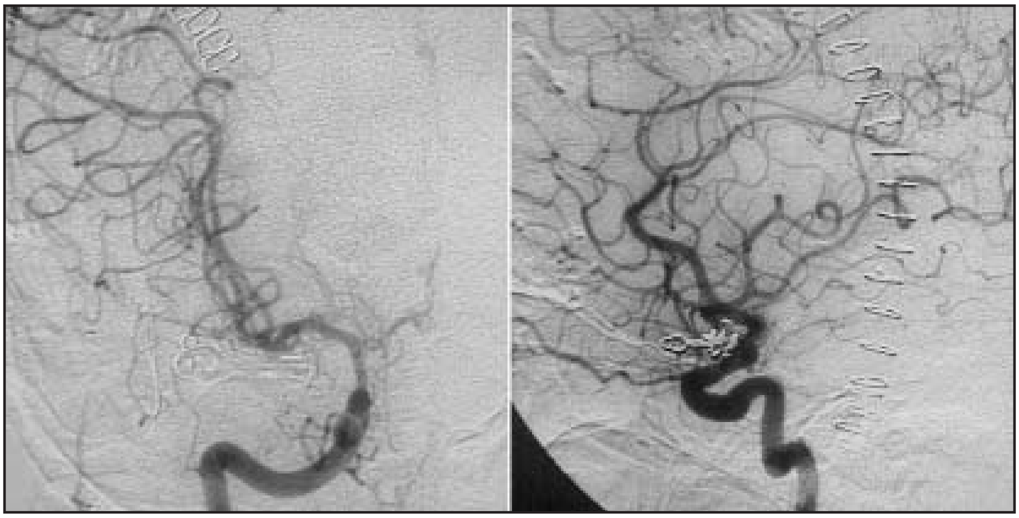


Fig 5. Frontal (A) and lateral (B) postoperative angiogram confirming complete obliteration of the aneurysm with preservation of the MCA.

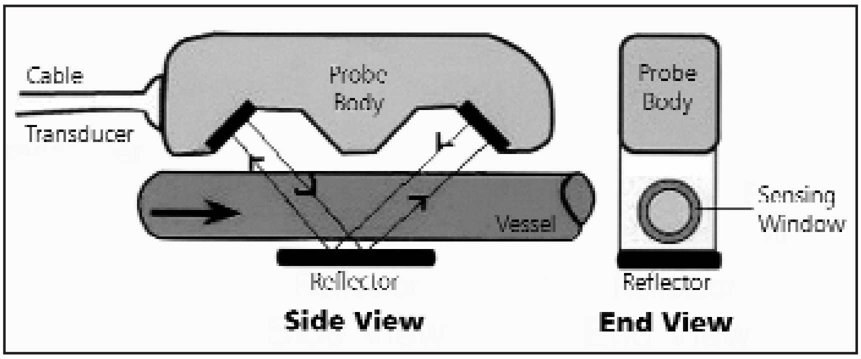


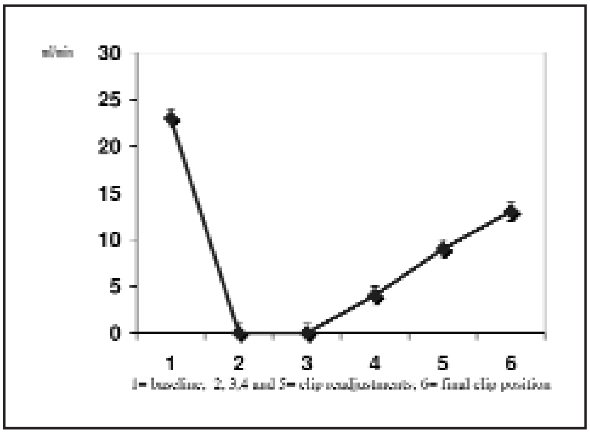
Fig 6. Schematic illustration of the ultrasonic transit-time principle.

ed with three clips. This allowed a complete occlusion of the aneurysm. Flow within MCA was redemonstrated using the microvascular ultrasonic flow probe after the temporary clips were removed. One of the branches was found having no flow in it. By readjusting the clips multiple times, flow within all MCA segments was able to be preserved, particularly in the inferior M2 segment (Graphic). The aneurysm was found to be well occluded with no evidence of leakage. After clip readjustment, flow in the M1 segment was normal and flow in the inferior M2 decreased to 12.6 ml/minute (Fig 4A), whereas flow in the superior M2 increased to 43.6 ml/minute, indicating that there was a compensatory increase in response to the reduced inferior M2 flow. It is important to note that, based on visual inspection alone, the surgeon had been satisfied with the clip placement. It was the low flow reading in the MCA segments that prompted the surgeon to adjust the clip (Fig 4. B). Postoperative angiography confirmed complete obliteration of the aneurysm with preservation of the afferent vessel (Fig 5A and B). The patient has had a good outcome with no focal ischemic deficit postsurgery.

DISCUSSION

The goals of aneurysm surgery are to eliminate the aneurysm from the intracranial circulation and to maintain the patency of normal vessels. Traditionally, verification of these goals has been provided by observation with the use of an operating microscope. It is well recognize that visual inspection of the clip alone or audio Doppler signals used to detect flow compromise during aneurysm surgery are subjective methods that can be inadequate or misleading some cases. It is not always possible to visualize fully the area encompassed by the clip. Likewise, flow velocities increase in the presence of stenosis and thus a strong Doppler signal may, in fact, be associated with a reduction in lumen diameter and a decrease in blood flow.

Angiography is considered the gold standard for assessing vessel-flow compromise after aneurysm clipping, but it is not performed routinely at most



Graphic. Mean blood flow measuments (ml/min) within inferior M2 segment of MCA demonstrated using de microvascular flow probe during aneurysm clipping and after multiple clip readjusment.

Table 1. Blood flow within MCA demonstrated using de microvascular flow probe.

MCA segment	M1	M2 superior	M2 inferior
Baseline	26.7	32.4	22.8
After coil and temporary clip removal	11.0	24.4	0.2
After clip adjustment	17.6	40.1	0
Final value after multiple clip adjustment	26.0	43.6	12.6

institutions. The equipment and personnel are not universally available and the technique is expensive and time consumig[8]. Furthermore, the delay in obtaining information about blood flow may be unacceptable and the complication rate of angiography is by no means negligeble (1.7 to 2.9%)[8,9].

Nevertheless, several studies have documented the rates of vessel occlusion or clip adjustment based on angiographic findings[5-7,10,11]. In a series of 66 patients who underwent postoperative angiography, Macdonald et al.[5] reported that there were unexpected stenosis in nine out of 78 (11.5%) patients, resulting in six strokes and two deaths (10.3%). Futhermore, in the same study there was a 4% incidence of unexpected residual aneurysm and an additional 4% incidence of completely unclipped aneurysms. In a subsequent study, routine intraoperative angiography revealed an unsuspected arterial occlusion or residual aneurysm, leading to clip adjustment in 11 % of cases[10].

Origitano et al.[6] reported on the rate of clip adjustment made on the basis of intraoperative angiography in 40 consecutive patients harboring 54 aneurysms, 52 of which were clipped. Intraoperative angiography prompted clip adjustment in 18 (34%) of the 52 aneurysms. Twenty-two percent of these clip adjustments were due to parent artery stenosis, 44% for residual aneurysm, and 33% for both. Eighty-eight percent of the clip adjustments were necessary on large or giant aneurysms. In addition, the authors found that aneurysms located at anatomical sites with multiple inflow and distal outflow vessels and midline, deep, and ophthalmic lesions had a highly significant association with clip adjustment.

Derdeyn et al[11]., also demonstrated that the frequency of clip adjustment is associated with the size and location of the aneurysm. In their series, intraoperative angiography prompted clip adjustment in 46 (16.8%) of 273 patients. The highest rates of clip adjustment occurred in aneurysms of the superior hypophyseal artery (38.9%), superior cerebellar artery (60%), and internal carotid bifurcation (33.3%), suggesting that aneurysms in these locations warrant more intensive monitoring to avoid vascular compromise. In another study, Payner et al[7]. reported that intraoperative angiography, when used selectively based on the surgeon's concern about possible vessel stenosis branch occlusion, or residual aneurysm, led to immediate repositioning of the aneurysm clip in 27% of cases. Bailes et al.[1] investigated 35 patients who underwent surgery for the treatment of 42 cerebral aneurysms using a microvascular Doppler ultrasonography. They found an incidence of 31% for unexpected stenosis of adjacent arteries.

The flow probe uses ultrasound transit-time technology to measure blood flow. The body of the probe houses two piezoelectrical crystals that alternatively transmit and receive an ultrasonic signal in both upstream and downstream directions with respect to the flow of blood (Fig 6). Using wide-beam illumination, the two transducers pass ultrasonic signals back and forth, alternately intersecting the vessel in upstream and downstream, directions. The flowmeter measures the "transit time" it takes for a wave of ultrasound to travel the fixed distance from one transducer to the other. The difference between the upstream and downstream integrated transit times is a measure of volume flow. The vessel is placed within a beam that fully and evenly illuminates the entire blood vessel and the transit time of the wide beam becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.

The ultrasonic beam intersects the vessel twice on its reflective pathway. During each intersection, the transit time of the beam is modified by a vector component of the flow. The full beam senses the sum of these two vector components, that is, the flow itself. If the angle of the beam is changed with respect to the flow, one vector component of the flow becomes greater and the second vector component diminishes, with little consequence to their sum. The accuracy of the transit-time method of blood volume flow measurement has been extensively validated[12-16].

Quantitative flow measurements facilitate optimal clip placement by providing immediate verification that flow in the parent vessel and distal outflow branches are fully preserved. Obviously, repositioning the clip has inherent risks. If vessel stenosis or occlusion is suspected, the microflow probe is very helpful in confirming flow integrity and avoiding unnecessary adjustments. In addition to assessing flow integrity in the parent vessel and distal branches after aneurysm clipping, we have found as Nakayama et al.[17], the microflow probe to be useful for measuring residual flow and collateral supply during temporary clipping or aneurysm trapping, and for evaluating the patency of extracranal-intracranial bypasses. The limitation of perivascular ultrasound transit-time flow probe relate to the inability to detect aneurysmal rests or residual neck. A subject of interest to future investigations is to determine the values of mean blood flow reduction which is of physiological relevance and when it is necessary to adjust the clip placement.

In conclusion, the ultrasound transit-time flow probe provides objective, non-invasive cerebral blood flow measurements in real time in the parent single-vessel and distal outflow branches intraoperatively during cerebral aneurysm surgery. In cases in which vessel-flow compromise is detected, the clip can be repositioned within a few minutes, resulting in immediate improvement in blood flow and minimal ischemic time. The ultrasonic perivascular micro-flow probe can be useful tool in the management of intracranial aneurysms.

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