

## Original Article

## Monitoring of brain tissue oxygenation in surgery of middle cerebral artery incidental aneurysms

A. Cerejo, P. A. Silva, C. Dias<sup>1</sup>, R. VazDepartments of Neurosurgery and <sup>1</sup>Intensive Care, Hospital S. João, Porto, Portugal

E-mail: \*A. Cerejo - a.cerejo@sapo.pt; P.A. Silva - pietroaps@yahoo.com; C. Dias - mcelestedias@gmail.com; R. Vaz - ruimcvaz@gmail.com

\*Corresponding author

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**This article may be cited as:**Cerejo A, Silva PA, Dias C, Vaz R. Monitoring of brain tissue oxygenation in surgery of middle cerebral artery incidental aneurysms. *Surg Neurol Int* 2011;2:37.Available FREE in open access from: <http://www.surgicalneurologyint.com/text.asp? 2011/11/2/78250>**Abstract**

**Introduction:** The management of incidental unruptured aneurysms remains a matter of controversy; middle-sized or large anterior circulation incidental aneurysms, in young or middle age patients, should be considered for treatment. Surgical clipping is an accepted treatment for middle cerebral artery unruptured aneurysms. Ischemic events can occur even in cases of incidental aneurysm surgery. Since regional cerebral blood flow can be compromised due to temporary arterial clipping or to incorrect placement of definitive clip, we performed intra-operative monitoring of brain tissue oxygen concentration (PtiO<sub>2</sub>), to detect changes in brain oxygenation due to reduced blood flow, eventually leading to ischemia, during surgery of middle cerebral artery incidental aneurysms.

**Methods:** PtiO<sub>2</sub> monitoring was performed during surgery of eight patients harboring incidental MCA aneurysms, using a polarographic microcatheter (Licox, GMS – Kiel, Germany), placed in the temporal lobe on the side of the lesion, from dural opening to dural closure.

**Results:** Basal values varied between 2.3 and 27.3 mmHg; these values are lower than those previously described in the literature as “normal” for uninjured brain or in cases of subarachnoid hemorrhage. In all patients, a significant decrease in PtiO<sub>2</sub> was found in every period of temporary clipping of MCA. Post-operative infarction in the territory of middle cerebral artery occurred in one patient and, in that case, there was a persistent minimum value of 0.6 mmHg, without recovery after the placement of the definitive clip. In another patient, an incorrect placement of the definitive clip could be predicted by a decrease in PtiO<sub>2</sub> value.

**Conclusions:** PtiO<sub>2</sub> monitoring during aneurysm surgery shows brain tissue perfusion in real time and there is a correlation between any episode of reduced blood flow to the affected vascular territory during surgery and a decrease of PtiO<sub>2</sub> values. Unexpected low basal values were obtained in “uninjured” brain, with no influence from subarachnoid hemorrhage. The values of risk for brain infarction during temporary arterial occlusion still need further studies, but an incomplete recovery or a persistent fall in PtiO<sub>2</sub> values after definitive clipping should be considered as an indication for verification of the position of the clip.

**Key Words:** Aneurysm, incidental, middle cerebral artery; monitoring, PtiO<sub>2</sub>, surgery

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## INTRODUCTION

Middle cerebral artery incidental aneurysms, larger than 5 mm, in patients younger than 70 years, should be considered for treatment, and surgery is the treatment of choice in most cases.<sup>[9,11,13,17,22]</sup> Regional circulatory interruption by application of temporary clips is a current technique in aneurysm surgery, for safer dissection of the aneurysm and for control of intra-operative aneurysm rupture. However, ischemic events can occur with the possibility of post-operative cerebral infarction,<sup>[1,6-8,10,12,16,19,21]</sup> even in cases of incidental aneurysm surgery, either due to temporary arterial clipping or to incorrect placement of the definitive clip.<sup>[1,5,7,12,15,18,19,21]</sup> We performed intra-operative monitoring of brain tissue oxygen concentration (PtiO<sub>2</sub>), to evaluate PtiO<sub>2</sub> values in "normal brain" and to detect changes in brain oxygenation, due to reduced blood flow, that may be indicative of high risk for cerebral ischemia and post operative brain infarction during surgery of middle cerebral artery incidental aneurysms. In unruptured aneurysms, variations in brain oxygenation are directly dependent on the surgical events, without the influence of changes in the intracranial pressure or cerebral blood flow induced by the presence of subarachnoid hemorrhage.

## MATERIALS AND METHODS

Eight patients submitted to surgical treatment of middle cerebral artery incidental unruptured aneurysms were studied. The study was approved by the Ethics Committee, and an informed consent was obtained for inclusion.

Two male and six female patients were included, and the mean age was 58.5 years (median 59,5 years). In all cases, the diagnosis was obtained during the study of headache. All patients were admitted in the Neurocritical Care Unit after surgery and, in every case, a CT scan was performed in the first 6 to 8 h after surgery, and a new CT scan in days 4 to 7 after surgery. The presence of vasospasm was determined by transcranial Doppler, executed every day in the first 4 days after surgery. Outcome was graded using the Glasgow Outcome Score, 1 month after surgery.

All patients were anesthetized with total intravenous anesthesia. Accordingly with our current procedure, the arterial blood pressure and PaCO<sub>2</sub> were maintained as stable as possible during surgery (middle arterial pressure values between 70 and 87 mmHg, PaCO<sub>2</sub> values between 31.3 and 34.0 mmHg).

PtiO<sub>2</sub> and brain temperature were monitored using an oxygen probe (Licox, GMS, Germany) and a temperature catheter. After durotomy, both were standardly placed in the middle temporal gyrus, on the side of the aneurysm,

2 cm below the sylvian fissure, and inserted 25 mm into the cerebral tissue, distanced 5 mm one from the other. Catheters were marked to maintain a constant depth, continuously checked, during surgery. PtiO<sub>2</sub> values were measured in mmHg. Brain temperature was also stable in all cases, between 34.9 and 36.8 °C.

In all cases, temporary clips were applied to middle cerebral artery, proximal to the aneurysm, during surgery. In seven cases, temporary clips were used to facilitate aneurysm dissection, but, in 1 case, a temporary clip was used for control of intra-operative aneurysm rupture. Cerebral protection agents were not used.

PtiO<sub>2</sub> basal value was considered as the value registered immediately before the first application of a temporary clip. PtiO<sub>2</sub> values during temporary clipping were registered, and the amplitude of decrease (percentage from the basal value) and the lowest value obtained in each patient were studied. The recovery of PtiO<sub>2</sub> values after definitive clipping was evaluated in all cases; final and basal values were compared and the time elapsed until the final value was achieved after the placement of the definitive clip was registered.

## RESULTS

The results are summarized in Table 1.

Basal values of PtiO<sub>2</sub> ranged from 2.3 to 27.3 mmHg (median 9.6 mmHg). Basal values below 10 mmHg were found in five cases. The time elapsed from the placement of the PtiO<sub>2</sub> catheter to the first application of a temporary clip ranged from 12 to 72 min, depending on the time needed to identify and dissect the aneurysm complex.

In all cases, temporary clips were used during surgery. The number of periods of temporary regional circulatory interruption was variable from case to case, with a minimum of 2 periods and a maximum of 11 periods. In seven patients, temporary clips were used to facilitate aneurysm dissection, but in one case there was an intra-operative aneurysm rupture. The approximate duration (in minutes) of circulatory interruption ranged from 1 to 9 min.

There was a significant decrease in PtiO<sub>2</sub> values in every application of temporary clips, with variations ranging from 20% to 80%, comparing to the values registered before the application of the temporary clip. The minimum PtiO<sub>2</sub> value obtained during each period of temporary circulatory interruption varied from 0.9 to 10.4 mmHg. In three of the eight cases included, PtiO<sub>2</sub> values of less than 2 mmHg were found when temporary clips were applied. The lowest PtiO<sub>2</sub> value persisted for 2 min or more in four cases, lasting no longer than 1 min in the remaining four cases. The persistence of the lowest PtiO<sub>2</sub> value was related to the duration of temporary regional

Table 1: Results of the study (per case number)

#	Sex/age	Basal value (mmHg)	Time to basal value (minutes)	Periods of circulatory interruption	Time of circulatory interruption (minutes)	Decrease of PtiO <sub>2</sub> (%)	Lowest value (mmHg)	Duration of lowest value (minutes)	Recovery after definitive clipping (% from basal)	Time of recovery (minutes)	Infarction CT scan	Vasospasm TC Doppler	Glasgow Outcome Score
1	F 69	8.2	40	2	2-4	67-77	2.4	2	10.5 (128)	3	---	---	5
2	M 54	27.3	72	8	1-3	41-63	10.4	1	28.3 (104)	1	---	---	5
3	F 49	14.1	12	2	1-1	20-47	7.9	1	6.0 (4)	4	---	---	5
4	F 59	2.3	20	4	1-4	36-62	1.2	4	10.9 (77)	4*	---	---	5
5	M 63	14.8	18	3	1-4	36-72	4.2	4	7.1 (309)	2	---	---	5
6	F 53	9.7	13	11	1-5	21-74	1.4	1	10.8 (73)	3	---	---	5
7	F 60	9.5	18	6	1-5	50-76	2.3	1	8.2 (85)	8	---	---	5
8	F 61	7.8	28	5	2-9	46-80	0.9	9	10.3 (108)	6	---	---	5
									0.6 (8)	29**	Infarction ACM		3

\*Recovery time after replacement of the definitive clip. \*\*No recovery after definitive clipping

circulatory interruption, ranging from 1 to 9 min.

In all cases, the definitive clip was applied under regional circulatory interruption using a temporary clip. In six cases, there was a recovery of PtiO<sub>2</sub> values after the placement of the definitive clip, in a percentage of 70% or more comparing to the basal values. The time elapsed for recovery, in these six patients, ranged from 1 to 8 min. In case 3, [Figure 1], the PtiO<sub>2</sub> value after definitive clipping was 7.9 mmHg, but decreased to 6.0 mmHg (43% of the basal value) during the following 4 min. After verification of the position of the definitive clip, by direct visual inspection, a partial occlusion of a M2 branch was verified. The position of the clip was changed and there was a recovery of the PtiO<sub>2</sub> value to 10.9 mmHg (77% of the basal value) in the next 4 min. In case 8 [Figure 2], a regional circulatory interruption of 9 min due to an intra-operative rupture in the neck of the aneurysm was necessary to control bleeding. During this circulatory interruption, the PtiO<sub>2</sub> value decreased from 4.6 to 0.9 mmHg (decrease of 80%), recovering to

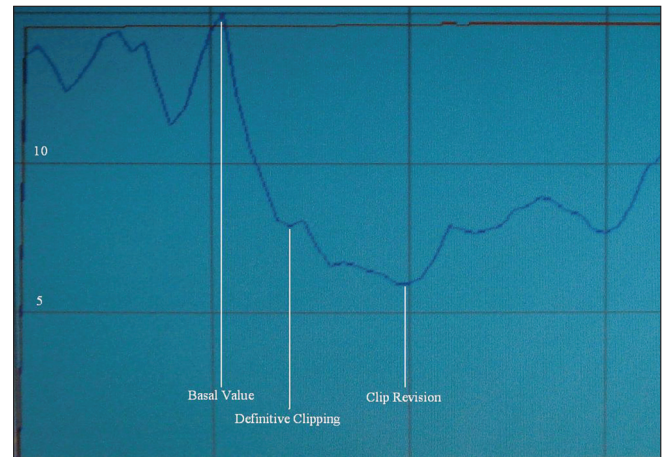


Figure 1. Schematic diagram of monitoring in case 3

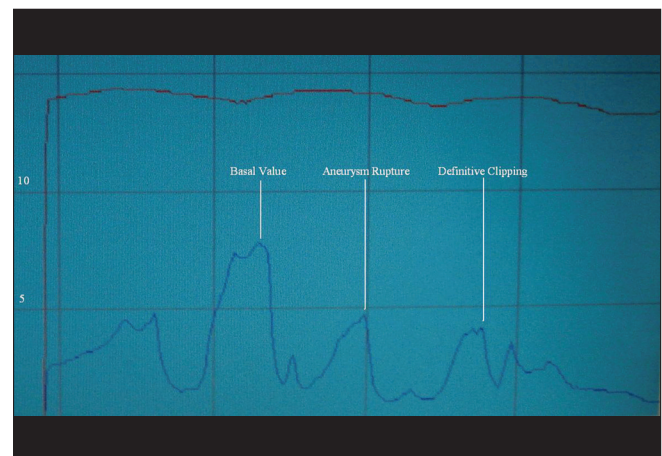


Figure 2. Schematic diagram of monitoring in case 8

4.0 mmHg after 6 min. A new application of a temporary clip and the placement of the definitive clip led to a fall in PtiO<sub>2</sub> value from 4.0 to 1.5 mmHg, recovering to 3.2 mmHg after withdrawal of the temporary clip. However, there was a persistent fall to 0.6 mmHg, during 29 min, after the placement of the definitive clip. Again, the position of the clip was verified, and a relative stenosis of one M2 branch was found. Nevertheless, due to a very difficult control of the bleeding point of the aneurysm and to an apparently appropriate blood flow under local inspection, the position of the clip was not changed.

CT scan was performed in the first 6 to 8 h after surgery, and a new CT scan in days 4 to 7 after surgery. Infarction in the territory of middle cerebral artery on the side of the aneurysm was detected on CT scan in patient 8.

Transcranial Doppler was routinely used in every patient in the first 4 days after surgery. Values compatible with vasospasm were not detected.

The clinical outcome was verified 1 month after surgery in all patients, using the Glasgow Outcome Score (GOS). Patients were evaluated by a staff member not involved in the treatment of the patient or in this research work. Except for patient 8, the GOS was 5. Patient 8 had a GOS of 3, due to infarction in the territory of middle cerebral artery on the side of the aneurysm.

## DISCUSSION

Surgery is currently used for treatment of incidental unruptured middle cerebral artery aneurysms.<sup>[11]</sup> Intra-operative aneurysm rupture and ischemia dependent on prolonged regional circulatory interruption or inadequate placement of the definitive clip leading to vascular occlusion and post-operative brain infarction are direct causes of mortality and morbidity related to surgery.<sup>[1,5,7,12,15,18,19,21]</sup> Temporary clips are used to deal with intra-operative aneurysm rupture and to facilitate aneurysm dissection, and a method of monitoring that could predict the danger for ischemia during temporary clip application and after the placement of definitive clip could be an important contribution for the safety of aneurysm surgery.

In this study, the partial pressure of tissue oxygen (PtiO<sub>2</sub>) was monitored during surgery, in patients without subarachnoid hemorrhage. PtiO<sub>2</sub> and temperature probes were placed in a standardized way, in an attempt to avoid variations due to different positions of the catheters. PtiO<sub>2</sub> reflects the oxygen concentration in a small area of the brain tissue (a sensitive surface of 7.1 mm<sup>2</sup> around the probe), depending on the cerebral blood flow, under stable conditions of brain temperature.<sup>[2,4,8,10,16,20]</sup> Therefore, the regional circulatory interruption by the use of temporary clips leads to a decrease in PtiO<sub>2</sub> values,<sup>[2,4,8,10,16,20]</sup> and the same may

happen if there is an incidental total or partial occlusion of branches of middle cerebral artery by the definitive clip. In this work, we try to establish values of PtiO<sub>2</sub>, during surgery, that may indicate a high risk for post-operative ischemic lesions.

### Basal values

Basal values were variable, with a minimum of 2.3 mmHg and a maximum of 27.3 mmHg and, as in previously reported works,<sup>[8]</sup> a reason for this variation was not found. Since all the patients had incidental aneurysms, values considered normal for uninjured brain should be expected, but the basal values were significantly lower than normal values.<sup>[14]</sup> Basal values were also lower than those described previously in the literature in cases of subarachnoid hemorrhage,<sup>[1,6,8,10]</sup> and those usually found in cases of traumatic brain injury, with values below 10 mmHg in four cases.<sup>[2,4,16,20]</sup> An explanation for that fact was not found, and there was no relationship with the occurrence of post-operative infarction, vasospasm, or with the final outcome.

### PtiO<sub>2</sub> values during temporary clipping

Intra-operative monitoring of PtiO<sub>2</sub> was a very sensitive (100%) method of detecting a decrease in the oxygen available for cell consumption when there was a circulatory interruption during middle cerebral artery aneurysms surgery. In fact, whenever a temporary clip was applied, a significant decrease (20% or more, comparing with the basal value) in PtiO<sub>2</sub> values was found. Unlike previous works,<sup>[6,8,10]</sup> only middle cerebral artery aneurysms were included (without significant collateral blood flow when Middle Cerebral artery is temporarily occluded), and this is a possible explanation for this very high sensitivity.

The amplitude of the decrease ranged from 20% to 80%, being always superior to 60% when the circulatory interruption lasted for 3 min or more although decreases superior to 60% were also found with shorter periods of temporary clipping.

The minimum PtiO<sub>2</sub> value registered during surgery was below 2 mmHg in three patients, and between 2 and 3 mmHg in other two cases. Considering the experience with brain trauma patients,<sup>[2,4,16,20]</sup> these values are referred as being of high risk for brain ischemia.<sup>[2,4,16,20]</sup> A minimum value of less than 2 mmHg lasting for 2 min or more was registered in two patients. In one of these patients, there was also a decrease of PtiO<sub>2</sub> of 80%, comparing to the basal value, during temporary clipping and no recovery after placement of the definitive clip. This patient developed a middle cerebral artery infarction after surgery.

### Recovery after definitive clipping

In two cases (cases 3 and 8) there was no recovery or there was a persistent fall in PtiO<sub>2</sub> values after the

placement of the definitive clip and withdrawal of the last temporary clip. In these patients, the verification of the position of the definitive clip showed partial or total occlusion of MCA branches. In case 3, the clip position was changed, therefore allowing for recovery of  $PtiO_2$  value, and the post-operative period was uneventful. In case 8, the clip position was not changed and the patient developed post-operative brain infarction in the territory of middle cerebral artery, evident in the CT scan 48 h after surgery. Therefore, an incomplete recovery or a persistent decrease in  $PtiO_2$  values after definitive clipping should be considered a strong indication for reviewing the position of the clip.

## CONCLUSION

Intra-operative monitoring of partial pressure of tissue oxygen ( $PtiO_2$ ) is a very sensitive method of detecting the decrease of oxygen for cell utilization, due to decreased blood flow, during temporary clipping and after definitive clipping, in middle cerebral artery incidental unruptured aneurysm surgery. "Basal values", obtained without the influence of subarachnoid blood, were lower than expected in "uninjured" brain, and this fact, although unexplained, should be kept in mind in future investigation in this field. Although values that could be predictive of brain ischemia could not be established, an incomplete recovery or continuous decrease in  $PtiO_2$  values after definitive clipping should be considered an indicator of high risk for the development of post-operative brain infarction, and, therefore, an indication for verification of the position of the clip.

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