Subarachnoid hemorrhage (SAH) is a serious condition, with high morbidity and mortality. In most cases, SAH is caused by rupture of an intracranial aneurysm. A poor prognosis may be related to the development of post-operative vasospasm and occurrence of ischemic lesions. Also, mortality and morbidity may be directly related to surgical treatment of ruptured and unruptured aneurysms, usually in association with intraoperative aneurysm bleeding and with ischemia due to prolonged regional circulatory interruption or inadequate placement of the definitive clip leading to vascular occlusion. Temporary clips are often used to control intraoperative aneurysm rupture and to facilitate aneurysm dissection. The main problem is that the regional circulatory interruption may cause ischemic lesions, leading to postoperative brain infarction and increased morbidity and mortality. The rate of ischemic complications could theoretically be reduced by using an intraoperative method of monitoring brain oxygenation during temporary clipping and after definitive clipping.

Brain tissue partial pressure (PtiO2) was prospectively monitored for evaluation of brain oxygenation during aneurysm surgery, studying basal PtiO2 values and their association with the development of post-operative vasospasm, and changes in brain oxygenation that may indicate a high risk of ischemia during temporary clipping and after definitive clipping.

Methods

PtiO2 was monitored during surgery of 37 patients, 28 with SAH (13 Middle Cerebral Artery (MCA), 7 Carotid/Posterior Communicating Artery (Pcom) and 8 Anterior Communicating Artery (AcoA) aneurysms) and 9 incidental aneurysms (8 MCA and 1 AcoA aneurysms), using a polarographic microcatheter directly inserted in the cerebral tissue. Twelve male and 25 female patients were studied, and the mean age was 49.6 years. All patients were operated in the first 48 h after the onset of SAH. Clinically, they were evaluated with Hunt and Hess scale, and computed tomography (CT) scans were evaluated with Fisher scale. Vasospasm was determined by
transcranial Doppler (TCD), executed every day in the first week after surgery, and the occurrence of brain infarction was studied with post-operative CT scan. Outcome was graded using the Glasgow Outcome Score (GOS), 3 months after surgery.

Basal values were studied, as was the association between basal values and the occurrence of post operative vasospasm in SAH cases.

Temporary clips were applied during surgery in all cases. The sensitivity of this method of monitoring during temporary clipping in different aneurysm locations was evaluated. PtiO2 values during temporary clipping and the recovery of PtiO2 values after definitive clipping were studied for detection of changes in brain oxygenation, due to reduced blood flow, that may be indicative of high risk for cerebral ischemia and post operative brain infarction.

Results

Basal values were studied by statistical analysis in an attempt to establish associations between a number of variables. In our series, patients that developed TCD vasospasm had significantly lower basal PtiO2 values than those that did not. In all cases developing TCD vasospasm, the PtiO2 basal value was below 10mmHg. A similar correlation with TCD vasospasm could not be established regarding age, Hunt & Hess or Fisher grading. Furthermore, statistical significance was not found when PtiO2 basal values were studied according to age, region of monitoring, clinical status or CT findings.

The sensitivity of the method was not the same in different regions of monitoring. In MCA aneurysms, there was a decrease in PtiO2 values (> 20% from the basal value) during every application of a temporary clip (100 % sensitivity). In Pcom aneurysms, there was also a fall in PtiO2 during temporary clipping (100% sensitivity), more evident in cases of clipping of Carotid Artery proximal and distal to the aneurysm and Pcom. In AcoA aneurysms, there was a much lower sensitivity, 31 and 44% in cases of unilateral and bilateral A1 temporary clipping, respectively.

In MCA aneurysms, the minimum PtiO2 value registered during temporary clipping was below 2 mmHg in 10 cases, values considered as an indicator of high risk for brain ischemia in cases of traumatic brain injury. These minimum values, considered individually, were not associated with development of brain infarction. However, in the 3 cases developing brain infarction in the territory of MCA, there was simultaneously an amplitude of decrease of PtiO2 values greater than 80% and a minimum value of less than 2 mmHg lasting for 2 or more minutes.
In 6 cases, there was an incomplete recovery (less than 60%, compared to basal values), no recovery or a persistent fall in PtiO2 values after definitive clipping. In 3 of these patients, partial or total occlusion of MCA branches was detected after verification of the position of the clip, leading to clip replacement and complete recovery of PtiO2 values. Postoperative brain infarction in the MCA territory developed in 3 of these 6 cases: the position of the clip seemed appropriate and was not changed in 2 patients and, in another case, it was changed after detection of occlusion of one branch of MCA trifurcation, but, previously to clip replacement, a PtiO2 value of 0 mmHg persisted for 10 minutes. Another case developed severe vasospasm and multiple ischemic lesions, probably not related to the surgical procedure.

Postoperative infarction in the territory of MCA developed in 3 patients. In these patients there were no criteria of vasospasm on TCD, and these ischemic lesions may be related to surgery. In the 3 cases, there was a coincidence of (a) decrease in PtiO2 of more than 80% compared to basal value; (b) minimum PtiO2 value below 2 mmHg lasting for 2 or more minutes; and (c) incomplete recovery or persistent decrease in PtiO2 values after definitive clipping.

In Pcom aneurysm surgery, conclusions about the significance of the monitoring data were not possible, since all patients developing post-operative infarction had vasospasm in TCD.

In AcoA aneurysms, the low sensitivity of the method and the fact that no patient developed post-operative infarction precludes further conclusions about the possibilities of this monitoring in surgery of aneurysms in this location.

**Conclusion**

Intra-operative monitoring of partial pressure of tissue oxygen (PtiO2) is a very sensitive method of detecting the decrease of oxygen for cell utilization, due to decreased blood flow, during aneurysm surgery, and can bring useful information about the risk of ischemia.

In our results, low PtiO2 basal values registered per operatively were associated with an increased prevalence of post operative TCD vasospasm, and this association was independent of other clinical or radiological parameters.

In MCA aneurysms, this monitoring can be helpful to detect situations of high risk of ischemia, during temporary clipping or due to inadequate position of the definitive
clip. When using temporary clips, the occurrence of an abrupt decrease in PtO2 values, together with a very low minimum value persisting for 2 or more minutes may indicate a high risk for ischemic lesions. After definitive clipping, careful inspection of the position of the clip is recommended when there is an incomplete recovery or fall in PtO2 values.

Further studies are needed concerning the usefulness of PtO2 monitoring during Pcom and AcoA aneurysm surgery, and the simultaneous utilization of blood flow monitoring may bring important information on this issue.