



Is the surgical repair of unruptured atherosclerotic aneurysms at a higher risk of intraoperative ischemia?

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ABSTRACT

Background: The incidence of ischemia might be increased in the surgical repair of atherosclerotic unruptured aneurysms compared to non-atherosclerotic aneurysms. The atherosclerotic wall might increase the occurrence of thromboembolic events or its rigidity might endanger the occlusion of perforators within the aneurysm vicinity.

Methods: 87 patients (53 patients without and 34 patients with atherosclerotic unruptured aneurysms, 50.5 ± 9.7 years) were analyzed for severity of atherosclerosis within the aneurysm and the aneurysm bearing vessel, surgical maneuvers, intraoperative alterations in evoked potentials and clinical and neuroradiological results.

Results: Temporary vessel occlusion (25% vs. 50%, $p=0.021$), repositioning of a permanent clip (21% vs. 56%, $p=0.001$) and aneurysm remnants (2% vs. 18%, $p=0.012$) occurred more often in patients with atherosclerotic aneurysms. At 6 months, 3/34 patients with atherosclerosis (8.8%) had an unfavorable outcome, all patients without atherosclerosis had a favorable outcome ($p=0.056$).

Conclusion: The surgical repair of unruptured aneurysms is safe but patients with atherosclerotic altered vessels and aneurysms accounted to a minor increase in unfavorable outcome and an increased risk of morbidity at 6 months postoperatively. This factor should be taken into consideration when performing surgery of atherosclerotic, unruptured aneurysms.

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1. Introduction

With the increasing availability of modern imaging techniques and patients' demand for MRI-screening, incidental aneurysm findings are rising. The high incidence of atherosclerosis in an aging population and related diseases such as hypertension or diabetes increases the prevalence of atherosclerotic altered aneurysms. The neurosurgical treatment of unruptured aneurysms ranges between 3 and 40% and the mortality rate between 0.4 and 1.5% depending on age, size and location of the aneurysm [1–6]. While performing surgical repair of aneurysms manipulation associated vessel occlusion

of vessel branches or perforators, intended temporary vessel occlusion or reconstructive technique due to complex aneurysm structure are associated risk factors. Despite the aforementioned factors, the atherosclerotic wall itself might add risk towards the occurrence of intraoperative ischemia and thus increase patients' morbidity. This has not been systematically analyzed in a larger patient group [7]. Several methods are intraoperatively utilized to reliably detect factors potentially associated with impending ischemia. Intraoperative ultrasound doppler sonography, angiography and more recently indocyanine green angiography have been introduced to directly assess blood flow alteration within vessels directly exposed during surgery [8–15]. Disadvantages of these methods are that blood flow impairment more distant to the exposed surgical side remains unrecognized and that the relation between the extent of blood flow alteration and ischemia can only be estimated. Neurophysiological monitoring with evoked potentials (EPs) was implemented for real-time assessment of the conductivity of somatosensory, auditory and motor pathways [16–21]. This aims at “functional” assessment of neuronal pathways dependent on the vascular supply of the surgically exposed

Abbreviations: ICA, internal carotid artery; AcomA, anterior communicating artery; ACA, anterior cerebral artery; MCA, middle cerebral artery; ISUIA, International Study of Unruptured Intracranial Aneurysms.

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vessels. Disadvantages of these methods might be considered the high specificity for the assessed pathways, thus lacking the assessment of other cortical areas. In vascular neurosurgery, the reversible alteration of intraoperative recorded EPs indicates transitory ischemia. Irreversible EP-alteration, especially EP loss, are strongly correlated to permanent ischemia and thus to long term neurological sequelae [19–23].

This study analyzes whether the surgical repair of arteriosclerotic compared to non-arteriosclerotic aneurysms was more often related to (a) critical surgical steps such as temporary vessel occlusion and repetitive clip placement; (b) a higher incidence of unfavorable outcome being indicated by EP-alteration and (c) a distribution of infarcts indicative for thromboembolic events. These results are compared to published data on this issue and might help in further tailoring treatment for unruptured aneurysms.

2. Patients and methods

2.1. Patient population

The study was approved by the local ethics committee and patients gave written informed consent. Patients' information including patient characteristics, treatment, radiological features, and the presence of an SAH were prospectively entered in an SPSS database (SPSS Institute, Inc., Chicago, IL, USA). Inclusion criteria for this study were elective surgery for an unruptured aneurysm and intraoperative neurophysiological monitoring with somatosensory and motor evoked potentials (SEPs; MEPs). Our treatment algorithm for unruptured aneurysms follows the recommendations of the German Society of Neurosurgery and the results have been published recently [24,25]. For each patient the treatment is discussed interdisciplinarily with neurologists, endovascular neuroradiologist and vascular neurosurgeons. The clinical neurological status was evaluated preoperatively, within 24 h postoperatively, and after 6 months following surgery by a senior attending neurosurgeon. Clinical outcome was determined according to the grading and changes of the modified Rankin Scale (mRS). The outcome was determined as good, if the mRS grading was either unchanged – regardless of the preoperative status – or changed into mRS 1. Patients' outcome was considered "moderate", if the change was into mRS 2. Patients' outcome was considered "unfavorable", if the outcome deteriorated into mRS 3–5. The occurrence of new postoperative ischemia was additionally assessed with a head CT scan (<24–48 h after surgery, which was standard of care). The postoperative angiography was analyzed for vessel stenosis or occlusion in relation to the clip position.

2.2. Anaesthesia

Following a standardized protocol, anaesthesia was induced with a bolus of propofol (1.5–2.5 mg/kg), suffentanil (0.3–0.5 µg/kg/h) and a short-acting muscle relaxant (rocuronium, 0.6 mg/kg bolus) for intubation only and further maintained with sevoflurane or isoflurane at 0.5 MAC and suffentanil (0.3–0.5 µg/kg/h). After dura opening methohexital (0.5 mg/kg induction bolus, 4–8 mg/kg/h) was added for neuroprotection and administered at a level to achieve a burst-suppression pattern in the EEG. During temporary vessel occlusion the mean arterial blood pressure was kept >90 mmHg; the oxygen concentration of the ventilation was increased to 80–100%.

2.3. Management of intraoperative neurophysiological monitoring

Intraoperative neurophysiological monitoring was performed with alternating transcranially elicited MEPs and SEPs according

to a protocol previously being described in detail [19,20,22]. During the clipping procedure, those MEPs and SEPs reflecting the vascular territory of interest were continuously monitored in an alternating mode. MEPs and SEPs of the non-operated hemisphere were intermittently recorded in 15–30 min intervals. In MEPs, an increase of the stimulation intensity of more than 20 mA, an amplitude decrement of more than 50% or a potential loss and/or an SSEP-amplitude decrement for more than 50% or a loss of the response in three consecutive recordings were considered as significant warning signs. Those criteria have been deduced from experimental and clinical studies, which could demonstrate that permanent changes exceeding the above mentioned extents are very likely to be followed by neurological deficits. These parameters have been summarized in international recommendation on intraoperative neuromonitoring during surgery for SEPs [26]. The warning criteria for MEPs follow empirical evidence [27,28] and have been refined more recently [29]. To follow by immediately notifying the surgeon, the recent surgical step was reconsidered and – if possible – to immediate action, e.g. replacement of permanent clip.

2.4. Description of atherosclerotic findings

The distribution and severity of atherosclerosis was assessed according to the surgeons' intraoperative findings either retrospectively (35 patients, surgical reports) or prospectively (52 patients). Atherosclerotic changes in the vessel or the aneurysm walls were categorized as following: (a) "mild" atherosclerosis: yellowish, spotty appearance of the vessel and/or aneurysm, which the surgeon felt at the time would have little or no effect on the elasticity of the wall and the ability to place any clip in any location; (b) "moderate" atherosclerosis: multiple atherosclerotic plaques affecting the aneurysm bearing wall, which affects the elasticity of the wall in such being partial rigid and thus potentially affect the choice of the clip; (c) severe calcification of the aneurysm bearing vessel or the aneurysm itself, resulting in severe rigidity of the vessel or aneurysm wall and hampering temporary vessel occlusion (e.g. clip placement has carefully to be chosen between atherosclerotic plaques) or permanent clip placement (e.g. not allowing the complete closure of the clip arms).

3. Data analysis

Severity and distribution of atherosclerosis, surgical steps (temporary vessel occlusion, placement or reposition or application of multiple permanent clips, retractor placement), intraoperative alteration (reversible, irreversible) in SEPs and MEPs were correlated with early and long term postoperative morbidity and neuroradiological outcome.

3.1. Statistical analysis

For statistical analysis of endpoints and possible co-factors Fisher's exact test was performed [30]. In case of multiple testing we did a Bonferroni-correction. For differences between subgroups after performing Komolgorov–Smirnov-test, we either choose Student's *t*-test or Mann–Whitney-*U*-test. Further a logistic regression was performed to analyze the effects of aneurysm size, age (both continuous variables), atherosclerosis and alteration in EPs (both binary variables) with outcome. For comparison with literature, PubMed and EMBASE were searched with Boolean search for the following key words: age; atherosclerosis; unruptured aneurysm; incidental aneurysm; intraoperative evoked potentials; morbidity and mortality.

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