The Impact of Temporary Artery Occlusion During Intracranial Aneurysm Surgery on Long-Term Clinical Outcome: Part I. Patients with Subarachnoid Hemorrhage

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Key words
- Subarachnoid hemorrhage
- Temporary artery occlusion

Abbreviations and Acronyms
CT: Computed tomography
GOS: Glasgow Outcome Scale
HH: Hunt and Hess
ISAT: International Subarachnoid Aneurysm Trial
SAH: Subarachnoid hemorrhage
TAO: Temporary artery occlusion

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BACKGROUND: **Temporary artery occlusion (TAO) during intracranial aneurysm surgery is an integral element in facilitating aneurysm dissection and clipping. Despite its significance, knowledge of effects of TAO on long-term clinical outcome is limited. The purpose of this study was to evaluate the impact of TAO in patients with subarachnoid hemorrhage (SAH) at one institution.**

METHODS: **Patients managed for an intracranial aneurysm were followed from January 2000 to July 2009. This study included a cohort of patients with a diagnosis of SAH who underwent TAO during aneurysm surgery. Risk factors known to affect outcome were considered. Effects of TAO time on long-term clinical outcome were evaluated using the Glasgow Outcome Scale (GOS) at last follow-up visit or hospital discharge. Analyses included descriptive statistics and binary logistic and ordinal logistic regression.**

RESULTS: **Inclusion criteria were met by 382 patients (74.3% female, age 52 years ± 13.5) with aneurysmal SAH. Mean follow-up was 39 months ± 57.3. Mean TAO time was 19.4 minutes ± 15.7. Of patients, 66% had a good outcome and made a complete recovery at last follow-up (GOS 5); 13% of patients were moderately disabled (GOS 4); and 27% of patients were severely disabled (GOS 3), were in a vegetative state (GOS 2), or had died (GOS 1). Overall, TAO time had no effect on overall long-term clinical outcome ($P = 0.76$). Higher Hunt and Hess grades ($P < 0.001$), Fisher computed tomography grades ($P < 0.001$), age ($P < 0.001$), larger size of aneurysm ($P < 0.008$), aneurysms of the posterior circulation ($P = 0.044$), and presence of clinical vasospasm ($P < 0.001$) were significantly associated with worse outcomes. On logistic regression analysis, the association between location of aneurysm (anterior vs. posterior circulation) and outcome disappeared.**

CONCLUSIONS: **Limited duration of TAO during aneurysm surgery did not affect long-term clinical outcome and appears to be safe in patients with aneurysmal SAH. Established SAH risk factors including Hunt and Hess grades, Fisher computed tomography grades, and presence of clinical vasospasm clearly correlated with long-term clinical outcomes.**

INTRODUCTION

Temporary artery occlusion (TAO) during intracranial aneurysm surgery facilitates aneurysm dissection and clipping. Temporary occlusion of ≥1 vessels feeding the aneurysm reduces the pressure within the aneurysm, lessening the risk of intraoperative aneurysm rupture. In complicated aneurysms, arrest of arterial blood flow allows opening of the aneurysm for atheromatous plaque removal and patent vessel reconstruction from a broad-based aneurysmal neck (33). Since its first description by Pool (28), who credited Jefferson with the first use of elective temporal occlusion in aneurysm surgery, this integral and valuable adjunct to intracranial aneurysm surgery has gained wide acceptance and is broadly used among cerebrovascular neurosurgeons. Despite its significance for intracranial aneurysm repair, few studies have scientifically evaluated the effects of TAO. Generally, studies have recommended limiting the duration of TAO to <15–20 minutes to avoid neurologic complications (3, 11, 19, 24, 26, 28, 30-32), even though TAO of 90 minutes without clinical sequelae has been reported (20). Most of these studies used radiologic or clinical evidence of stroke attributable to TAO as their primary endpoint, and clinical follow-up was frequently short and limited to the in-hospital stay. The purpose of this study was to evaluate the impact of TAO during intracranial aneurysm surgery on long-term clinical outcome. Part I includes patients who underwent aneurysm clipping in the setting of subarachnoid hemorrhage (SAH); Part II focuses on elective aneurysm surgery.

METHODS

This study was approved by the institutional review board (X09111900B). Patient demographics, aneurysm characteristics, details of the clipping procedure including information on TAO, and other important risk factors on all patients who underwent

clipping of an intracranial aneurysm by the senior author (W.S.F., III) at the University of Alabama at Birmingham were prospectively entered into a database at the time of their aneurysm surgery. Data collection by the authors was retrospective in nature; however, as noted previously, independent variables have been recorded by health care providers at the time of initial presentation, and the patients have been followed up by clinicians for the outcome variable.

Surgery was performed under normovolemic, normotensive, and normothermic conditions. Induction of anesthesia was accomplished with administration of propofol given over a background infusion of the narcotic remifentanil. After the induction of general anesthesia, a nondepolarizing muscle relaxant was given, and the trachea was intubated. When endotracheal placement was confirmed, remifentanil was given for hemodynamic control with background anesthesia provided by the inhalational agent isoflurane. Dexamethasone (10 mg intravenously) and mannitol (0.25 g/kg intravenously) were given at the time of scalp incision followed by furosemide (10 mg intravenously) 10 minutes later. TAO was used at the surgeon's discretion for complex aneurysms and for intraoperative aneurysm rupture. If there was >1 episode of TAO, temporary clips were removed, and 15 minutes of reperfusion was allowed in between TAO episodes.

At the conclusion of the case, all agents were discontinued, and the patient was allowed to emerge from the general anesthetic. The inhalational agent was primarily removed by respiratory means, and remifentanil was broken down by blood and tissue esterases independent of renal or hepatic breakdown mechanisms. The muscle relaxant was reversed with a combination of glycopyrrolate and neostigmine. The endotracheal tube was removed after full reversal of the paralyzing agent.

For Part I, the database was queried for patients diagnosed with aneurysmal SAH who underwent TAO during their clipping procedure. Effects of TAO on clinical outcome were evaluated using the Glasgow Outcome Scale (GOS) at the last follow-up visit or discharge from the hospital. Data are expressed as mean and SD, median and range, or frequency and percentage, whenever appropriate. The comparison between groups was performed using Mann-Whitney U test, Pearson χ^2, or Cramer V test. Normality of data was assessed by Kolmogorov-Smirnov test with Lilliefors correction. A binary logistic regression analysis with standard method was performed with outcome (GOS 1–4 [bad outcome] vs. GOS 5 [good outcome]) as dependent variables and age, gender, ethnicity (white vs. nonwhite), location of aneurysm (anterior vs. posterior circulation), Fisher SAH computed tomography (CT) grade (1–2 vs. 3–4), aneurysm size (1–10 mm vs. >10 mm), admission Hunt and Hess (HH) score (1–2 vs. 3–5), cerebral vasospasm, and total arterial occlusion time as independent variables. Non-gaussian data were rank-transformed using Rankit formula before inclusion in the regression model. Collinearity statistics and diagnostics (tolerance, variance inflation factor, condition index, and variance proportions) were checked according to recommended guidelines. A P value <0.05 was considered to indicate statistical significance.

Table 1. Patient Characteristics and Risk Factors

Total number of patients	382
Total number of aneurysms	422
Number of patients with ≥1 aneurysms (%)	
1 aneurysm	344 (90%)
2 aneurysms	36 (9%)
3 aneurysms	2 (1%)
Age (± SD)	52.1 ± 13.5 years
Gender, no. (%)	
Male	98 (25.7%)
Female	284 (74.3%)
Ethnicity, no. (%)	
White	230 (60.3%)
Black	139 (36.5%)
Hispanic	4 (1.1%)
Other	9 (2.1%)
Hypertension	179 (46.9%)
Smoking	182 (47.7%)
Family history	26 (6.8%)
Cocaine	10 (2.6%)
Hunt and Hess, no. (%)	
1	23 (6%)
2	185 (48.4%)
3	119 (31.2%)
4	47 (12.3%)
5	8 (2.1%)
Fisher CT, no. (%)	
1	22 (5.8%)
2	121 (31.7%)
3	96 (25.1%)
4	143 (37.4%)
Time from SAH to surgery (± SD)	2.1 ± 2.8 days

CT, computed tomography; SAH, subarachnoid hemorrhage.