Early surgery-related complications after aneurysm clip placement: an analysis of causes and patient outcomes

NANCY McLAUGHLIN, M.D., AND MICHEL W. BOJANOWSKI, M.D., F.R.C.S.(C)

Division of Neurosurgery, Centre Hospitalier de l’Université de Montréal–Hôpital Notre-Dame, Montreal, Quebec, Canada

Object. Most reports of series on ruptured intracranial aneurysms contain information on select intraoperative complications. An understanding of all surgical complications, however, may guide us toward improved surgical procedures and enrich discussions concerning alternative management strategies, such as endovascular treatment, which are not exempt from complications and aneurysm recurrence.

Methods. The study consists of a retrospective review of the charts, images, and notes from follow-up visits of 143 consecutive patients with subarachnoid hemorrhage (SAH) who were surgically treated during a 3-year period by one neurosurgeon. A surgical complication was determined based on findings of a clinical and/or radiological study in the absence of confounding factors such as the initial SAH ictus, vasospasm, hydrocephalus, and septic status. Functional outcome was assessed between 2 and 3 months post-SAH by using the Glasgow Outcome Scale (GOS). A procedure-related surgical complication was diagnosed in 29 (20.3%) of 143 patients studied. A brain tissue injury, including cerebral edema and hemorrhagic contusions, was diagnosed in 6.3% of patients, an unpredicted residual aneurysm neck in 5.3% of patients, and a cranial nerve deficit in 2.8% of patients. Functional outcome was good in 22 (75.9%) of the 29 patients with surgical complications. Death due to a surgical complication occurred in one (0.7%) of 143 patients.

Conclusions. Surgical complications are more prevalent than previously thought. They may have been overlooked previously because of the high percentage of good functional outcomes and low mortality rates in this group. The identification of surgical complications may encourage the search for solutions to improve surgical treatment of aneurysmal SAH.

KEYS WORDS • cerebral aneurysm • subarachnoid hemorrhage • surgical complication • functional outcome • mortality rate

In the past several decades, management of aneurysmal SAH has significantly changed. Advances in microsurgical, endovascular, and overall medical treatment have modified the incidences and causes of morbidity and death. Rebleeding and vasospasm have been reported to be the leading causes of unfavorable outcome. More recently authors have stated that early surgery combined with administration of calcium channel blocking agents almost eliminates the risk of recurrent bleeding and reduces the chance of a DIND. Nevertheless, many patients with aneurysmal SAH still die and not all survivors are neurologically intact.

Great progress has been made in the areas of neuroanesthesia, surgical instruments, and surgical techniques; however, most reports of ruptured intracranial aneurysms only show occurrence of select intraoperative complications. Intraoperative aneurysm rupture has been reported to be the most common and most devastating technical complication and may be attended by catastrophic consequences depending on the timing of the rupture during surgery.

The contribution of other surgical complications to rates of morbidity and mortality is variable. Currently, complications related to the surgical procedure are not well classified. Their analysis may guide toward improved surgical procedures and enrich discussions concerning alternative management strategies, such as endovascular treatment, which is not exempt from complications and aneurysm recurrence.

The goals of this study were to determine the incidence of various surgical complications and to analyze outcomes of patients with surgical complications.

Clinical Material and Methods

The design of this study was a retrospective review of data on consecutively admitted patients with aneurysmal SAH who underwent surgical treatment at Hôpital Notre-Dame, University of Montreal, between April 1998 and April 2001. Information was obtained from patient charts, surgical reports, reviews of radiological investigations, and notes from follow-up visits. The diagnosis of aneurysmal SAH was based on the following factors: 1) clinical signs and symptoms; 2) positive findings on a CT scan or in fluid obtained from a lumbar puncture; and 3) findings on angiography or, in rare cases, MR angiography, or an intraoperative diagnosis in cases in which the patient’s clinical presentation stressed the need for urgent surgical treatment. All

Abbreviations used in this paper: ACA = anterior cerebral artery; ACoA = anterior communicating artery; CT = computerized tomography; DIND = delayed neurological ischemic deficit; GOS = Glasgow Outcome Scale; IAR = intraoperative aneurysm rupture; ICA = internal carotid artery; MCA = middle cerebral artery; PCoA = posterior communicating artery; MR = magnetic resonance; SAH = subarachnoid hemorrhage; VBA = vertebrobasilar artery.
Early surgical complications after aneurysm clip placement

Cerebral angiography studies performed at our center include at least anteroposterior, lateral, and oblique views. All SAHs received Hunt and Hess grades at patient admission and again preoperatively. The patient’s functional health was assessed between 2 and 3 months post-SAH at a follow-up appointment. The GOS was used for this assessment; good recovery and moderate disability were jointly accepted as a favorable outcome, and severe disability, vegetative survival, and death were considered a poor outcome.

Case Management

All patients who presented to the emergency department with aneurysmal SAH, which was assigned Hunt and Hess grades between I and III, were considered surgical candidates. Patients presenting with higher Hunt and Hess grades were considered for surgical treatment unless no cerebral activity was demonstrated on the clinical evaluation or a preoperative CT scan revealed an intraparenchymal hemorrhage that was massive and/ or located in a brain region in which the functional prognosis was expected to be poor. Supportive treatment was given to these patients with their family’s agreement. Patients scheduled for aneurysm clip placement procedures received normal saline to maintain their normovolemia. Systolic blood pressure was maintained below 150 mm Hg. A ventriculostomy was placed before angiography in patients with symptomatic hydrocephalus. Aneurysm clip placement procedures were performed as soon as possible after the initial SAH ictus and arrival to our center.

Surgical interventions were performed at a teaching hospital where residents actively participate in operations under the supervision of the attending neurosurgeon (M.W.B.). Brain relaxation was achieved by osmotic diuresis and head position, allowing judicious cerebrospinal fluid drainage via a ventriculostomy. Most aneurysms were exposed through a pterional approach; a frontoorbitotomy was used for some aneurysms located on the ACoA. Large openings of the sylvian and basal cisterns reduced the need for brain retraction. The minimal necessary tension on cerebral tissue induced by the brain retractor was frequently released during the operation. No subpial dissection was performed. When necessary, especially for ACoA aneurysms that pointed posteriorly behind the pericallosal arteries, approximately 5 mm of the gyrus rectus was removed. Standard microvascular techniques and magnification were used in all patients. The use of temporary clips and the maximum duration of clipping were assessed by reviewing operative reports. The bone flap was not put back in place in most patients with high Hunt and Hess grades to diminish the risks of possible complications due to increased intracranial pressure.

Postoperatively, all patients were admitted to the intensive care unit for close monitoring of their neurological and hemodynamic statuses. Calcium channel blocking agents were administered and normovolemic and normotensive states were maintained. Clinical vasospasm was defined according to the following criteria: 1) the insidious onset of a decreased level of consciousness and/or a local deficit occurring 4 to 12 days after SAH; and 2) the exclusion of other causes such as rebleeding, intracerebral hematoma, hydrocephalus, metabolic disturbances, and surgical complications. When vasospasm was clinically suspected, aggressive hypervolemia, hypertension, and hemodilution treatment was introduced. At our center, angiography was performed in most cases of suspected vasospasm and angioplasty was performed when necessary. Findings on postoperative CT scans and angiograms were compared with images obtained preoperatively.

Definition of Surgical Complications

A complication related to the surgical procedure was considered on a clinical basis when either a focal deficit (hemiparesis or cranial nerve palsy) or a deteriorated state of consciousness was noted within the first 24 hours after surgery and had been absent during the preoperative period. A surgical complication was considered on a radiological basis when images obtained within the first 3 days after surgery revealed radiological findings compatible with a specific morbid process that had been absent on preoperative images. Patients’ charts were reviewed to determine the existence of possible confounding factors that could have contributed to postoperative clinical deterioration such as the initial SAH ictus, vasospasm, hydrocephalus, and septic status. A surgical complication was declared responsible for the patient’s postoperative deterioration when other postoperative complications could not account for new symptoms. We classified surgical complications into four categories: 1) direct nerve tissue injuries such as brain tissue or cranial nerve injuries; 2) intracranial vascular complications; 3) surgical complications related to the craniotomy; and 4) other complications related to the surgical procedure that are not specified by the other categories. When various causes could be used to explain new postoperative radiological or clinical findings, complementary investigations were undertaken to determine the specific cause.

Results

Three hundred twenty-five consecutive patients admitted to our hospital between April 1998 and April 2001 with aneurysmal SAH were retrospectively studied. At arrival, brain death was diagnosed in 27 patients. Of 179 patients who underwent aneurysm clip placement, 143 were surgically treated by one neurosurgeon (M.W.B.). The characteristics of the studied surgical population are presented in Table 1. The other 119 patients underwent endovascular treatment. Of the patients treated endovascularly during the study period, 74 were referred to the endovascular team by other neurosurgeons. Participation in a randomized international study explained the assignment of 10 patients to the endovascular option. Two patients chose coil embolization after they received counseling on both treatments. Thirty-three patients were initially examined by the neurovascular surgeon (M.W.B.) and referred to the endovascular team. The aneurysm location was the determinant factor in 17 patients: 12 patients presented with VBA aneurysms and five with carotid–ophthalmic aneurysms. The other 16 patients were allocated to the endovascular option because two or more of the following factors were present: advanced age, poor clinical grade, and/or severe medical condition.

Before surgery, all patients underwent cerebral CT scanning and all but seven patients underwent cerebral angiography. Of these seven patients, four patients presented in a clinical state requiring emergency surgical treatment; two patients presented with medical conditions that contraindi-
cated angiography, and MR angiography was performed instead; and one patient had previously presented with an intracranial aneurysm in Hunt and Hess Grade II. Of the 136 patients who underwent preoperative angiography, one patient underwent two angiography sessions and an MR imaging angiography study, the outcomes of which were all nondiagnostic. The patient’s evolving condition was compatible with a diagnosis of aneurysmal SAH and the decision was made to perform an exploratory craniotomy, which led to the discovery of two intracranial aneurysms. Of the 135 angiography studies performed preoperatively that yielded positive findings, 97 (71.9%) revealed a single aneurysm and 38 (28.1%) revealed multiple aneurysms. The locations and sizes of the aneurysms responsible for SAH are shown in Table 2. In two cases of multiple aneurysms the exact origin of the SAH could not be determined. Of the 135 angiography studies performed preoperatively that yielded positive findings, 97 (71.9%) revealed a single aneurysm and 38 (28.1%) revealed multiple aneurysms.

The locations and sizes of the aneurysms responsible for SAH are shown in Table 2. In two cases of multiple aneurysms the exact origin of the SAH could not be determined. Of the 141 aneurysms identified as responsible for SAH, 36.9% were located on the ACoA, 24.1% on the MCA, 20.6% on the PCoA, 7.8% on the ACA, 6.4% on the ICA, and 4.3% on the VBA. The dimensions of the aneurysms could not be determined by imaging studies in six patients who did not undergo preoperative angiography and for whom the operative report did not contain mention of an estimated macroscopic size of the lesion. Approximately 75% of the aneurysms identified as responsible for SAH were less than 10 mm in maximal diameter.

The delay between the SAH and aneurysm clip placement was less than 24 hours in 71 patients (49.7%) and less than 48 hours in 104 patients (72.7%). In 36 patients (25.2%) surgery was performed more than 72 hours after SAH; the main reasons for the delays were waiting for consultation and delay for transfer from referring centers.

The average duration of aneurysm surgery seemed comparable for all grades. Temporary clipping was noted in the operative reports of 116 patients and the maximal duration of temporary clipping was specified in 80 cases. A favorable outcome was achieved in 63 (80.8%) of 78 patients in whom temporary clipping lasted 15 minutes or less. In only two patients did temporary clipping last 16 minutes or longer. Among patients in whom the duration of temporary clipping was unknown, 94.4% had a favorable outcome.

Computerized tomography scanning was performed postoperatively in 142 patients (99.3%) and within the first 3 postoperative days in 131 patients (91.6%). Angiography was performed postoperatively in 132 patients (92.3%). Seven patients died before follow-up angiography could be performed, and four other patients did not undergo follow-up angiography. One patient presented with a poor preoperative Hunt and Hess grade and remained in a comatose state for many days after surgery. Although his level of consciousness and motor deficit gradually improved, no control angiography study was performed. One patient underwent two angiography sessions and an MR angiography study; none of these studies revealed any aneurysms. Two aneurysms were discovered during exploratory surgery. An MR angiography study was performed postoperatively. One patient with severe acute renal insufficiency and another patient with chronic renal insufficiency due to polycystic kidneys did not undergo postoperative angiography.

Surgical Complications

Twenty-nine (20.3%) of 143 patients in the studied population were found to have a surgery-related complication clinically and/or radiologically. One patient was found to have more than one complication. Overall, 31 complica-
Early surgical complications after aneurysm clip placement

<table>
<thead>
<tr>
<th>Hunt &amp; Hess Grade</th>
<th>No. of Patients w/ Surgical Complications (%)</th>
<th>No. of Patients w/o Surgical Complication (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>good/75 patients</td>
<td>16 (21.3)</td>
<td>59 (78.7)</td>
</tr>
<tr>
<td>intermediate/33 patients</td>
<td>10 (30.3)</td>
<td>23 (69.7)</td>
</tr>
<tr>
<td>poor/35 patients</td>
<td>3 (8.6)</td>
<td>32 (91.4)</td>
</tr>
</tbody>
</table>

* Surgical complications occurred in 29 patients.

The most frequently diagnosed surgical complication was brain injury, as diagnosed on the basis of new radiological findings and/or new neurological deterioration. Focal brain tissue lesions were described as intraparenchymal areas measuring 1 cm or less that appeared hypodense and were not related to a subarachnoid blood clot, intraparenchymal hematoma, or infarction. These lesions were present in nine (6.3%) of 142 patients who underwent a postoperative CT scan. After proceeding to additional images, most hypodense areas were considered to be due to focal cerebral edema. A favorable outcome was found in eight (88.9%) of nine patients and an unknown outcome in one patient (11.1%).

The second most frequently diagnosed surgical complication was unpredicted residual aneurysm rests, which are defined as the persistence of any portion of the original defect of the arterial wall without opacification of the aneurysm sac. Unpredicted aneurysm rests were found in seven patients (7.6%) of 91 patients who underwent postoperative angiography. After proceeding to additional images, most hypodense areas were considered to be due to focal cerebral edema. A favorable outcome was found in eight (88.9%) of nine patients and an unknown outcome in one patient (11.1%).

The third most frequently diagnosed surgical complication was cranial nerve deficit, which appeared in four (1.5%) of 132 patients. In two patients, no radiological evidence of vasospasm could not be determined definitively due to cerebral vessels did not fill during angiography, the definite contribution of vasospasm could not be determined in three. In two patients, no radiological evidence of vasospasm was found and arterial occlusion secondary to clip placement was diagnosed in two (1.5%) of 132 patients. Intraoperative aneurysm rupture occurred in one patient who presented with Hunt and Hess Grade V. The patient remained deeply comatose during the postoperative period and was transferred back to the referring center at the family’s request. No follow-up information was obtained 3 months after surgery.

The distribution of preoperative Hunt and Hess clinical grades in patients with and without surgical complications is presented in Table 4. Patients with surgical complications had good Hunt and Hess grades in 21.3% of cases, intermediate Hunt and Hess grades in 30.3% of cases, and poor Hunt and Hess grades in 8.6% of cases. Taking into account all confounding causes, patients with poor Hunt and Hess grades did not have more surgical complications than those with good ones.

The distribution of functional outcomes according to the GOS among patients with surgical complications is presented in Table 5. A favorable outcome was found in 22 (75.9%) of 29 patients with surgical complications and an unfavorable outcome in three (10.3%). Four patients were lost to follow up and their final GOS scores remain unknown. Three of these patients were moderately disabled and one remained in a vegetative state at the time of discharge.

If we only consider patients with surgical complications for whom the 3-month GOS score is known, 22 (88%) of 25 patients had favorable outcomes and three (12%) had unfavorable outcomes.

Of the 143 patients with surgically treated aneurysmal SAH, 117 (81.8%) had favorable outcomes, and 13 (9.1%) unfavorable outcomes. Outcome was undefined in 13 (9.1%) of the 143 patients, of whom only three had poor preoperative Hunt and Hess grades. Death followed aneurysm surgery in 10 (7%) of 143 patients. Death was attributed to a cardiopulmonary problem in two patients. In the other eight patients death was due to an intracranial phenomenon: the initial SAH in six patients, severe vasospasm in one patient (0.8%). No vasospasm was noted on the stenotic portion of the vessel. The patient had a favorable outcome. Arterial occlusion was shown to be due to distal emboli in one patient (0.8%). No vasospasm was shown on diagnostic angiography. The patient had an unfavorable outcome. Among the five patients in whom a segment of cerebral vessels did not fill during angiography, the definite contribution of vasospasm could not be determined in three. In two patients, no radiological evidence of vasospasm was found and arterial occlusion secondary to clip placement was diagnosed in two (1.5%) of 132 patients. Intraoperative aneurysm rupture occurred in one patient who presented with Hunt and Hess Grade V. The patient remained deeply comatose during the postoperative period and was transferred back to the referring center at the family’s request. No follow-up information was obtained 3 months after surgery.
and its complications in one patient, and a surgical complication resulting in vascular occlusion by distal emboli and hemorrhagic infarct in one patient. Therefore, the mortality rate associated with a surgical complication in this study was 0.7% (one patient).

**Discussion**

Improvements in the perioperative management of aneurysmal SAH as well as progress in neuroanesthesia and developments in surgical techniques and instruments have modified the morbidity and mortality rates associated with aneurysmal SAH.6,8,24 Yet, recurrent hemorrhage and vasospasm have been cited as the leading causes of unfavorable outcome after SAH,21,28 however, early surgery has reduced the incidence of recurrent bleeding and preventive administration of a calcium channel blocking agent (nimodipine) has reduced the incidence and severity of DINDs.1,15 The reduced incidence of clinical vasospasm recorded in more recent literature might also be due to specific clinical criteria of vasospasm and the exclusion of other conditions that can produce delayed neurological deterioration.4 The incidence of DIND in various studies has ranged from 1 to 14%.1,11,21 In agreement with these reports, in our study clinical vasospasm was diagnosed in eight patients (5.6%). The overall incidence of surgical complications was greater than the incidence of vasospasm. In cases in which aneurysm surgery has been performed, the vasospasm that occurs may not only be due to chronic irritation of blood on a vessel wall. Some vasospasm may be related to the surgical technique and, therefore, considered a surgical complication. Vessels are known to constrict in areas of ischemia, which may be induced intraoperatively by vessel manipulation, brain retraction, and intraoperative hypotension.28 Secondary vasospasm may potentiate the primary form of vasospasm and contribute to its clinical manifestations.27 Nevertheless, it is difficult to consider clinical vasospasm that occurs during the postoperative period as a surgical complication because it can occur in nonsurgical settings. If vasospasm were to be considered a complication related to surgical technique, one would expect to see associated brain tissue injury on CT scans. Many authors have studied intracranial vascular lesions and hemorrhagic infarct in one patient. Therefore, the mortality rate associated with a surgical complication in this study was 0.7% (one patient).

Surgical complications have not always been recognized as the major complication following aneurysmal SAH because authors have selectively studied specific complications.6,21 The incidence of surgical complications and their influence on patient outcomes may be difficult to compare between studies. Differences exist concerning what is considered surgery-related morbidity and mortality as well as how each specific incidence of morbidity is defined. Preoperative and postoperative cerebral angiography studies are not always performed routinely, which may lead authors to underestimate certain complications. Results may be influenced by the composition of the studied population and the time of surgery.

Our population with surgical complications is representative of the aneurysmal SAH population with regard to demographic characteristics. Patients with surgical complications were surgically treated less than 48 hours after ictus in 20 (69%) of 29 patients compared with 104 (72.7%) of 143 in the study population. In our series, the occurrence of overall surgical morbidity was not influenced by the timing of surgery.

Procedure-related complications were classified so that we could recognize surgical complications more adequately and to orient future efforts to diminish their occurrence (Table 3). The incidence of surgical complications has been reported to range from 4 to 25%.7,24 Twenty-nine (20.3%) of 143 patients in the present study were found to have a surgical complication. Brain tissue injury was the most frequent procedure-related complication; it occurred in 6.3% of the population studied. Hypodense areas on imaging studies were considered to have been caused by focal cerebral edema following brain retraction in the majority of cases. Although the majority of these patients were asymptomatic, their neurocognitive performances were not evaluated. The findings of brain tissue injuries may explain the neurocognitive findings observed in patients post-SAH. The reported incidence of hypodense areas related to the use of brain retractors ranges from 3 to 9%.6,16,21,22 Focal hypodense areas that were found were intraparenchymal, measured 1 cm or less, and did not surround an intraparenchymal hematoma. These focal hypodense areas probably went unnoticed because associated neurological deficits were rare and the GOS scores in these patients were good in 75.9% and unknown in 13.8%.

A cranial nerve deficit was diagnosed in 2.8% of patients; it occurred most frequently in patients with posterior circulation aneurysms due to the relationship between intracranial nerves and vessels. Of the six aneurysms originating from the VBAs, three were located at the basilar tip, two at the posterior inferior cerebellar artery origin, and one at the verteobasilar junction. The GOS scores were good in all patients and the cranial nerve deficit had either completely resolved or greatly improved by the follow-up appointment. Le Roux and colleagues17 observed postoperative cranial nerve abnormalities in 17% of patients with good Hunt and Hess grades and in 5.3% of patients with poor Hunt and Hess grades following the surgical repair of ruptured anterior circulation aneurysms. Awareness of the existence of even minor nervous tissue damage may encourage more careful manipulation of cerebral tissue.

Many authors have studied intracranial vascular lesions in different study populations. In a review of the literature, we found that the incidence of aneurysm remnants ranges from 3.8 to 8%, depending on the definition of remnant that is used.2,8,16,17 In our study, unpredicted residual aneurysms were diagnosed in 5.3% of patients with the aid of postoperative angiography. The majority of these aneurysms (five of seven patients) occurred on ACAs.7 All aneurysm remnants were reexamined by performing at least one cerebral angiography study 1 year later. During the short observation period in our study, no patient experienced rebleeding from the aneurysm remnant. The estimated annual risk of rebleeding from an aneurysm remnant is 0.38 to 0.79%.7 It must be compared with the rates of morbidity and mortality associated with repeated surgery.4,5

In our study no case of unpredicted persistent aneurysm was diagnosed. Both cases of persistent aneurysms, defined as the opacification of the aneurysm sac,25 were predicted and aneurysm exclusion was achieved postoperatively by endovascular treatment. Drake and Alcocock1 found a 13% incidence of persistent opacification of all or a significant portion of the aneurysm sac in patients who underwent...
Early surgical complications after aneurysm clip placement

Conclusions

Surgical complications seem more prevalent, albeit generally less dreadful, than clinical vasospasm. To improve surgical performance, it is imperative to recognize all procedure-related complications, regardless of how minimal they may seem. We hope this will allow the patient to benefit from a procedure that has been proven effective to exclude a ruptured aneurysm.

References


Manuscript received December 12, 2003. Accepted in final form June 9, 2004.
Address reprint requests to: Michel W. Bojanowski, M.D., Division of Neurosurgery, CHUM-Hôpital Notre-Dame, 1560 Sherbrooke Est, Montreal, Quebec, Canada H2L 4M1. email: michel.bojanowski.chum@ssss.gouv.qc.ca.