Intracranial Arterial Aneurysm — An Update

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THE PREVALENCE of intracranial aneurysms at autopsy appears to be between 2 and 5% depending on the composition of the series. In North America and Europe the incidence of subarachnoid hemorrhage (SAH) from rupture of an aneurysm is approximately 12 per 100,000 population. Approximately 25,000 new cases of ruptured intracranial aneurysm occur in the United States each year. About 50% of these patients die or become permanently disabled as a result of the initial hemorrhage, and another 25 to 35% die of a future hemorrhage if left untreated. The toll in death and disability from rupture of intracranial aneurysms has not changed substantially in the last 30 years, in spite of advances in both surgical and medical treatments of this illness. It is clear, then, that major efforts are needed to reduce the morbidity and mortality associated with rupture of intracranial aneurysms.

Diagnosis

The best way to decrease the morbidity and mortality associated with ruptured intracranial aneurysms is to increase our ability to recognize the existence of these lesions before they rupture. With such innovations as high-resolution computerized tomography (CT) and digital subtraction angiography, most intracranial aneurysms of significant size (greater than 7 mm) can be detected noninvasively. Individuals at high risk of harboring such lesions probably should be screened by these methods. Such individuals include the members of families in which more than one person is known to have an intracranial aneurysm. In addition, screening should be carried out in patients with diseases that predispose to the formation of intracranial aneurysms, such as fibromuscular dysplasia, polycystic kidneys, coarctation or hypertension of the aorta, or diseases associated with defects in vascular walls, such as Ehlers-Danlos and Marfan’s syndromes and pseudoxanthoma elasticum.

The most important impact, however, will be made by a greater awareness among the medical community of warning signs of aneurysmal rupture. Almost 40% of major aneurysmal ruptures are preceded by warning symptoms. Most of these symptoms fall into one of two major groups. The first consists of symptoms such as localized head pain, cranial nerve palsies (particularly of the oculomotor nerve), and visual defects that can be attributed to aneurysmal expansion. The second group of symptoms is thought to be caused by “minor leaks” and consists of generalized headache lasting several hours or days and frequently accompanied by nausea, neck pain, back pain, malaise, and occasionally photophobia. The alert physician can identify these patients who present with an unusually severe headache without a previous history of migraine, frequent headache, or psychosomatic complaints. A carefully performed lumbar puncture will show some evidence of fresh subarachnoid bleeding. The importance of recognizing these symptoms lies in the fact that when an aneurysm is diagnosed before a major rupture, it can be surgically eliminated with minimal morbidity, i.e., less than 2% combined mortality and major neurological morbidity in competent hands.

When a major SAH has occurred, one usually has little problem recognizing it, especially when the patient is alert and without major focal neurological deficits. The attack is usually heralded by severe headache of precipitous onset or sudden transient loss of consciousness followed by headache. The headache is described as “the most severe of my life,” “explosive,” “bursting,” “crushing,” etc. At the onset it may be localized to the suboccipital or frontal region, but it soon becomes generalized. Meningeal signs, such as photophobia and nuchal rigidity, develop several hours after the onset of the SAH and may be absent if the patient is seen soon after the hemorrhage. Subhyaloid hemorrhages (irregular bleeds of blood on the most superficial layer of the retina) are almost pathognomonic of SAH when seen on funduscopic examination in a patient without focal neurological deficits who complains of extremely severe headache of sudden onset.

Recognition is more difficult when the patient presents in coma or with major neurological deficits. If subhyaloid hemorrhages are seen in such a patient and there is no history of head trauma, SAH must be suspected and will be confirmed in about 50% of these cases. In the alert patient presenting with major neurological deficits, primary intracerebral hemorrhage or thrombotic or embolic stroke must be suspected first. SAH is unlikely in this setting unless an aneurysm has ruptured into the brain substance and produced an intracerebral hematoma.

Our group has recently reviewed the modern neuroradiological approach to the patient with SAH. A CT scan is obtained as soon as possible after admission. The initial CT scan is done without contrast to identify, localize, and quantify blood in the subarachnoid space. This is followed by a CT scan with contrast to identify...
the source of bleeding. Angiography at this stage is not necessary unless early surgery is planned or the patient has an intracerebral hematoma that might require prompt evacuation. When surgery is deferred for 8 to 12 days, as it usually is, complete cerebral angiography is carried out just before surgery. Many surgeons defer surgery if severe vasospasm is detected on the angiogram. When the patient deteriorates during the preoperative period, the CT scan, again, is most helpful in revealing the cause of deterioration.

Natural History

The natural history of asymptomatic, incidental, unruptured aneurysms is not well known. It has been estimated that they rupture at a rate of approximately 3% per year. A somewhat lower chance of rupture has been estimated by a different method using prevalence figures and decremental life-table analysis. Still, it appears that a young individual found to have an incidental aneurysm has at least a 15 to 20% chance of having a major SAH over the next 20 or 30 years of life. The natural history of ruptured intracranial aneurysms is better known. Approximately 20% of the patients die before ever reaching medical attention. Of those that reach a hospital, about 30% die during the next several days to months as a result of the initial hemorrhage or its complications. If the aneurysm is left untreated, about one-third of the patients that recover from the initial hemorrhage die as a consequence of recurrent bleeding. This incidence of rebleeding decreases with time, of course, so that by the end of two weeks, the chance of a recurrent hemorrhage within the next six months is only about 10%. Even at the end of six months, however, a patient who has recovered from an initial rupture continues to have about a 1% per year chance of suffering another hemorrhage.

Management of Ruptured Intracranial Aneurysms

General Measures

The patient with a recent SAH should be nursed in a quiet environment designed to prevent stress and excitement with accompanying abrupt changes in systemic arterial pressure. We routinely prescribe anti-convulsants to minimize the chance of a seizure. The use of steroids is reserved for patients with evidence of significantly increased intracranial pressure.

Blood pressure management is still controversial. The earlier tendency to lower the blood pressure artificially to hypotensive levels has been abandoned by most clinicians. Normotensive levels are ideal. When patients present with significant hypertension, a gradual, careful lowering of the blood pressure is desirable, provided the patient is alert and without major neurological deficits. If signs of cerebral ischemia develop, hypotensive treatment should be stopped in order to improve cerebral perfusion pressure.

Systemic Complications

Widespread hypothalamic dysfunction occurs frequently after aneurysmal hemorrhage. In general, many of these disturbances can be traced to overactivity of the sympathetic axis and overstimulation of both the adrenal cortex and the medulla. The severity of these disturbances correlates well with the severity of the hemorrhage and with the incidence and severity of vasospasm. Typical electrocardiographic changes found after SAH include peaked P waves, short P–R intervals, long Q–T segments, large U waves, and peaked T waves. At times more overt arrhythmias and frank subendocardial ischemia and infarction occur. These effects correlate closely with the levels of circulating catecholamines.

Of the electrolyte disturbances associated with SAH, hyponatremia is the most common. It usually becomes manifest a few days after the hemorrhage, and it frequently heralds the onset of symptomatic vasospasm. Usually, the low serum Na\(^+\) is accompanied by low serum osmolarity and high urinary Na\(^+\) and osmolarity, thereby partially fulfilling the diagnostic criteria for the syndrome of inappropriate antidiuretic hormone (ADH) secretion. In the pure form of this syndrome, however, both the total body fluid content and the intravascular volume are increased. The opposite has been found to occur in patients with hyponatremia after SAH. It has been postulated that the initial problem in this setting is loss of Na\(^+\) in the urine due to unknown factors and intravascular volume contraction due to supine diuresis, pooling, negative nitrogen balance, decreased erythropoiesis, and iatrogenic blood loss. This volume contraction stimulates the secretion of ADH, which in turn results in an exacerbation of hyponatremia by water retention. These patients must be treated not only by restriction of free water intake, but also by replenishment of intravascular volume with colloid and blood.

Neurological Complications

When a preoperative aneurysm patient who has recovered from an initial hemorrhage deteriorates neurologically and when systemic causes such as electrolyte disturbances or fever have been eliminated, we are usually left with three major causes of deterioration: hydrocephalus, rebleeding, and vasospasm.

Hydrocephalus occurs frequently after SAH. It can be acute and severe if the initial hemorrhage involved rupture into the ventricles. These patients require emergency ventriculostomy, which sometimes results in rapid improvement. Hydrocephalus can also occur gradually, and in these instances it is usually communicating and related to blockage of the subarachnoid pathways and interference with reabsorption of cerebrospinal fluid (CSF) by the blood in the subarachnoid space. Caution should be exercised in the treatment of this more insidious form of hydrocephalus since abrupt lowering of the intracranial pressure, such as can occur with ventricular drainage or lumbar puncture, can induce rebleeding. Many patients can be managed with steroids and perhaps mannitol or loop diuretics, and, more often than not, the hydrocephalus subsides. When the patient continues to deteriorate in spite of medical measures, a CSF drainage procedure must be carried out.

Rebleeding continues to be a major problem after
Vasospasm is currently the most important cause of morbidity and mortality in the patient who has recovered from an initial SAH. Twenty to 30% of these patients develop delayed ischemic neurological symptoms that cannot be attributed to hydrocephalus or rebleeding. This deterioration usually occurs between the fourth and the twelfth days after the initial hemorrhage. These patients invariably show angiographic evidence of severe narrowing of the intracranial vessels supplying the areas of the brain responsible for the symptoms. This degree of arterial narrowing is only infrequently found in the absence of clinical symptoms, but lesser degrees of narrowing are commonly seen on angiograms of asymptomatic patients at least four days after SAH. The clinical syndrome of vasospasm evolves gradually over a period of hours to days and, in this respect, differs from rebleeding, which usually occurs catastrophically. The patient becomes progressively symptomatic and, depending on the arterial territory involved, may exhibit confusion and lethargy, hemiparesis, aphasia, anosognosia, akinetic mutism, and/or frontal release signs. The syndrome may resolve gradually over a few days or progress relentlessly to coma and death within a period of hours to days. Various forms of therapy, such as vasodilators, alpha and beta blockers, calcium antagonists, and prostaglandin inhibitors, have been tried, but none has yet been conclusively found to be beneficial. Augmentation of cerebral perfusion pressure by expansion of intravascular volume, vasopressors, cardiac stimulants, and reduction of intracranial pressure seems to be the only effective measure widely used in the treatment of vasospasm today.

Although few advances have been made in the treatment of vasospasm, some progress is evident in our understanding of its etiology and our ability to predict which patients will become symptomatic from it. It seems clear that the blood clot around the vessels in the base of the brain is responsible for vasospasm. Vasospasm does not occur without such clots but almost invariably occurs when thick clots are detected on an early (within the first 72 hours) uncontrasted CT scan. Being able to predict which patients are at risk of vasospasm helps in the evaluation of therapy designed to prevent its occurrence. At present, our practice is to maintain an expanded intravascular volume with regular infusions of colloid in an effort to keep the cerebral perfusion pressure elevated in patients in whom severe vasospasm is predicted by the early CT scan.

Timing of Surgery

During the early years of direct intracranial surgery for aneurysms, surgeons learned that early surgery (within the first week) carried a very high morbidity and mortality. The brain is usually swollen, retraction is difficult, and vasospasm, if present, may be exacerbated. This realization led to the almost universal policy of deferring intracranial surgery until at least eight to ten days after SAH. Lately, however, a shift has occurred in some centers, particularly in Japan, towards very early (within 72 hours of SAH) surgery in all patients who are not comatose and do not present with a severe neurological deficit. It is argued that even though early surgery carries a higher morbidity, the prevention of vasospasm by washing out the subarachnoid clots and of rebleeding by clipping the aneurysm more than compensates so that morbidity and mortality are decreased in over-all case management. Early surgery also would make it safer to treat vasospasm aggressively with induced hypertension since the aneurysm would be secured. It is true that the results reported by these very experienced Japanese neurosurgeons compare favorably with the best statistics available when total case-management morbidity and mortality are considered. The results, however, may not be as good in less experienced hands. In a recent cooperative study conducted by 133 Japanese neurosurgeons, the mortality for early surgery in patients in good neurological condition was 26%. It is true that the results reported by these very experienced Japanese neurosurgeons compare favorably with the best statistics available when total case-management morbidity and mortality are considered. The results, however, may not be as good in less experienced hands. In a recent cooperative study conducted by 133 Japanese neurosurgeons, the mortality for early surgery in patients in good neurological condition was 26%. At present, we continue to defer surgery for 10 to 12 days in all patients except those who present, after a relatively minor hemorrhage, alert, without neurological deficit, and without a severe meningeal reaction. However, we will continue to rely on the results of a large international cooperative study on the timing of aneurysm surgery now being conducted by investigators at the University of Iowa.

Surgical Results

With new advances such as the operating microscope, safer anesthetic techniques, and, particularly, better selection of patients for surgery, the results of intracranial operations for aneurysm in experienced hands have improved significantly. From a mortality of approximately 30% to 35% about 15 years ago, some neurosurgeons are now reporting combined morbidity and mortality rates of under 15%. Aneurysms that previously were unmanageable, such as most basilar aneurysms and giant aneurysms, can now be approached with acceptable morbidity. A number of these lesions can now be treated with relative safety by ligation of the parent artery in conjunction with a...
microsurgical bypass graft designed to bring blood supply to the distal territory of the ligated artery.

**Future Prospects**

We hope that the question of "early" versus "late" surgery will be resolved in the next few years. We suspect that the answer will be mixed and that we will learn that some patients should be operated on early and some later. With our present ability to predict which patients will develop vasospasm, it is hoped that further advances in our understanding of the etiology of this condition will allow the development of satisfactory prophylactic therapy for patients at high risk. Further refinement of such techniques as detachable balloons that can be introduced percutaneously and stereotactic methods of producing thrombosis in the aneurysm may allow us to treat some of these lesions without a major craniotomy. Refinement of and greater experience with physiological techniques, such as blood flow measurements, positron emission tomography, nuclear magnetic resonance, central conduction time, etc., may improve our ability to choose the optimal time for surgery, depending on the physiological state of the brain. Finally, and most importantly, greater public awareness of the importance of "warning signs" of aneurysmal rupture, together with continuing advances in currently available noninvasive techniques such as the CT scan, digital subtraction angiography, and the electronic stethoscope, should allow us to detect an increasing number of aneurysms before they result in a catastrophic hemorrhage.

**References**

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