Craniotomy for the Treatment of Cerebral Aneurysms

BACKGROUND

Cerebral aneurysms (aneurysms in the brain) are dilatations (bubbles) of cerebral arteries. They occur in two varieties: saccular and fusiform. Saccular aneurysm are bubbles on the side of a blood vessel while fusiform aneurysms are enlargement of the whole blood vessel circumferentially. Saccular aneurysms usually occur at branching points of blood vessels. Individuals with cerebral aneurysm are thought to be born with weakening in the wall of the artery which over time expands forming a bubble on the wall of the artery. While the current thought is that individuals with cerebral aneurysm are born with a weakened blood vessel, certain diseases increase the likelihood of developing cerebral aneurysms. Such diseases include but are not limited to the following: adult onset polycystic kidney disease, fibro muscular dysplasia, arterio-venous malformations, connective tissue disorders, Osler-Weber-Rendu Syndrome, and bacterial endocarditis. In addition, smoking increases the incidence of bleeding from cerebral aneurysms.

The incidence of cerebral aneurysms in the general population is approximately 5%. Most commonly cerebral aneurysms occur on blood vessels associated with the internal carotid artery. Anterior communicating artery aneurysms are the single most common: 30% of all cerebral aneurysms. Other aneurysms and their frequencies are as follows: posterior communicating artery- 25%, middle cerebral artery-20%, posterior circulation aneurysms-15%. Approximately 20-30% of all patients have multiple cerebral aneurysms. Figure 1: Circle of Willis

Aneurysms can also be divided in terms of size. Those greater than 25 mm are known as giant cerebral aneurysms. Size of an aneurysm is important to delineate as it not only guides management but also predicts the natural history. Symptoms associated with cerebral aneurysms arise through three mechanisms: enlargement of the aneurysm usually as there is bleeding within the wall of the aneurysm, rupture of the aneurysm, or when the mass of the aneurysm causes pressure on the brain.

SIGNS AND SYMPTOMS

Rupture of the aneurysm leads to bleeding within the brain and usually causes the worst headache in ones life. The blood within the brain also causes irritation to the covering of the brain producing neck stiffness, sensitivity to light, back pain, nausea, vomiting, etc. Those individuals with giant cerebral aneurysms can develop pressure on the brain. The location of such pressure determines the type of symptoms: seizures, weakness, vision changes, hormonal imbalance, changes in sensation, etc.

When an individual has the worst headache of their life, it is important to delineate whether they have a ruptured cerebral aneurysm. This clarification is important as it guides treatment and prognosis. Patients with asymptomatic aneurysms can be observed while those with ruptured aneurysms must be treated in a timely fashion in order to have a chance at survival.

To determine if an aneurysm has ruptured a CAT scan of the head is performed. Blood within the brain will appear as white streaks within the covering of the brain (subarachnoid space). However in 10-15% of cases the amount of blood within the brain is too small to be detected with the CAT scan. In such situations a spinal tap is performed to study the fluid that surrounds the brain (cerebral spinal fluid). There will be disproportionate amount of blood within the spinal fluid of an individual with a ruptured cerebral aneurysm. Figure II: CAT scan of the head showing subarachnoid hemorrhage.

Management

As stated above, patients with ruptured cerebral aneurysm are admitted to the intensive care unit of the hospital for further medical and surgical management. Medical management includes controlling high blood pressure, seizures, pain, hydration, etc. In addition, patients who are comatose or those
who have accumulation of fluid in the brain require the placement of a catheter into the natural, but enlarged cavities in the brain (ventricles). Normally the brain contains a constant amount of fluid at all times; however, this fluid begins to accumulate when blood mixes with it. Thus a catheter is placed in this obstructed fluid space of the brain in order to drain fluid and to monitor brain pressure. A central venous catheter is also placed within the larger veins of the body. This allows for quick access in giving medications/fluids in addition to being able to monitor heart function.

The next step in the management algorithm includes identifying the cerebral aneurysm. This is accomplished by performing a cerebral angiogram (very similar to cardiac catheterization). Cerebral angiogram is performed by gaining access to the femoral artery. Since all of the blood vessels within the body are interconnected, we are able to access the brain blood vessels by passing a catheter from the femoral artery into the blood vessels that feed the brain. Next, contrast is injected and pictures of the head are taken. The cerebral aneurysm will appear as a bubble on the artery. Risks of performing a cerebral angiogram are as follows: 1% chance of a stroke, 1-2 % chance of bleeding around the groin requiring blood transfusion, and kidney damage from the contrast used. Figure III: example of a cerebral angiogram.

With today's technology the pictures from the cerebral angiogram can be used to build three dimensional structure of the aneurysm. Such an analysis is important in the management of the aneurysm. Currently four treatment options exist to patients.

1. Observation.
2. Endovascular obliteration of the aneurysm.
3. Craniotomy for wrapping/material support of the aneurysm.
4. Craniotomy for clip ligation of the aneurysm.

The goal of surgery is to prevent future bleeding from the aneurysm while minimizing injury to the brain during the operation. For decades the gold standard of treatment has been open brain surgery (craniotomy) for occluding the neck of the aneurysm. Such a complex operation is made successful through the efforts of a team consisting of a surgeon, surgeon’s assistant, anesthesiologist, nursing staff, and a brain function monitoring staff. The average length of time is approximately 6 hours. Before proceeding with the operation, it is essential to communicate with the family possible risks. Such risks include but are not limited to bleeding, infection, stroke, paralysis, coma, failure of the procedure, kidney failure, limb loss, risks of anesthesia, and death.

The type of craniotomy may vary depending on the location of the aneurysm; however, in almost all situations a frontal-temporal craniotomy (pterional) will provide adequate access for clipping of the aneurysm. Figure IV: pterional craniotomy.

Before positioning the patient on the surgical table, a lumbar drain is placed which allows drainage of the brain fluid. Next the patient’s head is placed in a head clamp which is fixed to the operating room table. This allows the table to turn/move without changing the position of the patient’s head. The head is fixed such that it is tilted 20-30 degrees to the opposite side and placed in slight extension. This allows the frontal lobe of the brain to fall away thus preventing the need for retraction. A curvilinear skin incision is made starting at the front of the ear to the middle of the head. The skin and muscle are separated and retracted allowing for the frontal and temporal bones of the skull to be exposed. Next small holes within the skull are made. Through these holes the dura is stripped away from the skull in all directions. Next a cutting burr is used to connect all the holes in a fashion to allow for the maximum area exposed.

Once the bone is removed, the coverings of the brain are seen. This covering is cut in a curvilinear fashion and reflected to allow for exposure of the brain. Next the sylvian fissure is identified which separates the frontal and temporal lobes of the brain. The sylvian fissure is opened allowing retraction of the frontal and temporal lobes. This allows access to the base of the brain where the main brain arteries are housed. The internal carotid artery (the main brain artery) is identified and followed till the aneurysm is identified. At this moment anesthesiologist may place the patients brain in a
medication induced coma. This allows the brain to have low oxygen requirements and thus the main blood supply to the aneurysm can be shut off. The aneurysm is then dissected to better define the neck of the aneurysm. At this time a metal clip is placed across the neck thus preventing blood to the aneurysm while continuing to keep the parent blood vessel open.

To test whether the clip has shut off the blood supply to the aneurysm, a final cerebral angiogram is performed. If there is residual blood showing within the aneurysm then the clip has to be modified. Otherwise the clip is left in the original position if the angiogram shows that the aneurysm is occluded. Next the covering of the brain is sewn together and the bone flap is re-approximated to the surrounding bone with metal plate and screws. The muscle, fascia, and skin are finally sewn together. Patient is taken out of the medical induced coma and taken to the intensive care unit.

**Postoperative Care**

Over the next few weeks the patient is monitored for vasospasm and hydrocephalus. Vasospasm (narrowing of blood vessels) is a reaction that the brain blood vessels undergo in patients who have ruptured cerebral aneurysms. Severity of vasospasm is determined by the neurological exam and daily trans cranial dopplers (measurement of the velocity of blood flow within the blood vessels). In order to maintain the same amount of blood flow to the brain through narrow blood vessels, patient’s volume status and blood pressure are kept high. In addition, all patients are given a medication called nimodipine which helps protect the brain during vasospasm. Nevertheless, a proportion of patients develop severe vasospasm which is not responsive to medical management. In such cases the patient may undergo a cerebral angiogram to determine which blood vessels are in spasm. Then a balloon is guided into the artery in spasm and the balloon is inflated, dilating the narrowed artery to the brain.

Next it is important to determine which patients will require a permanent catheter to drain the fluid build up in the brain. Over a period of days the drainage from the catheters is stopped while the neurological status of the patient is followed. Subsequently a CT scan of the head is also performed to see if the fluid spaces are getting larger. If the fluid spaces get larger or the patient becomes more lethargic then the patient requires permanent catheter placement. Otherwise the catheter is removed. In patients requiring permanent catheter placement, a ventricular-peritoneal shunt is placed.

In the next phase of treatment, the physical therapy and social work teams are involved. Determination is made whether the patient would benefit from physical/neurological rehabilitation or whether they are stable to be discharge to home. Over the long run, fortunate individuals who survive this critical medical/surgical condition may take years to recover to their baseline neurological and physical functioning. Treatment of ruptured cerebral aneurysms requires a multidisciplinary team, time, and great family support. While the above outline represents the views of treating aneurysms at Thomas Jefferson University Hospital other institutions may use other approaches in order to gain the same goal.
**RELEVANT TERMS**

1. **Central Line**: large IV placed in the subclavian, femoral, or internal jugular veins.
2. **Sylvian (lateral) fissure**: space separating the frontal and temporal lobes of the brain.
3. **Cerebral aneurysm**: bubble on the arteries of the brain.
4. **Subarachnoid Hemorrhage**: Bleeding within the covering of the brain. Can be associated with trauma or cerebral aneurysm.
5. **Lumbar puncture**: spinal tap to obtain cerebral-spinal fluid.
6. **ACOM**: anterior communicating artery.
7. **PCOM**: posterior communicating artery.
8. **Ach**: anterior choroidal.
9. **ACA**: anterior cerebral artery.
10. **MCA**: middle cerebral artery.
11. **PCA**: posterior cerebral artery.
12. **Vasospasm**: narrowing of the blood vessels of the brain in reaction to the surrounding blood products from a ruptured cerebral aneurysm.
13. **Hydrocephalus**: enlargement of the fluid spaces of the brain from scarring due to blood products.
14. **Ventriculostomy**: catheter placed within the fluid space of the brain to decompress accumulated fluid.
15. **Craniotomy**: removing bone in order to perform open brain surgery.
FIGURES
1. Pericallosal artery.
2. Callosomarginal artery.
3. Anterior cerebral artery.
4. Ophthalmic artery.
5. Internal carotid artery.
6. Anterior choroidal artery.
7. Lenticulostrate arteries.
Circle of Willis showing three Berry Aneurysms
Abbreviations:

- ACI - internal carotid artery
- ACA - anterior cerebral artery
- ACM - middle cerebral artery
- BA - basilar artery
- VA - vertebral artery
- PCA - posterior cerebral artery
- PICA - posterior inferior cerebellar artery
Cerebral Aneurysm
CT scan showing subarachnoid hemorrhage