

*Penn State Hershey*  
**Neurovascular Services**



# Table of Contents

## Introduction

### PART I: NEUROVASCULAR DISEASES

- Stroke** ..... 2
  - Ischemic Stroke ..... 2
  - Hemorrhagic Stroke ..... 3
  - Carotid Artery Disease ..... 3
  - Stroke Prevention ..... 4
  - Carotid Endarterectomy ..... 4
  - Carotid Angioplasty & Stenting ..... 5
- Cerebral Aneurysm** ..... 6
  - Subarachnoid Hemorrhage ..... 7
  - Hydrocephalus and Vasospasm ..... 7
  - Microsurgical Aneurysm Clipping ..... 8
  - Endovascular Aneurysm Surgery ..... 9
- Vascular Malformations** ..... 10
  - Arteriovenous Malformations ..... 10
  - Microsurgical Excision of AVM ..... 10
  - Embolization ..... 11
  - Stereotactic Radiosurgery ..... 11
  - Cavernous Angioma ..... 12
  - Dural arteriovenous Fistula ..... 12
  - Carotid-cavernous Fistula ..... 13

### PART II: DIAGNOSTIC TESTING AND TREATMENT

- Diagnostic Tests** ..... 13
  - Carotid Duplex Scan ..... 13
  - CT Scan ..... 14
  - MRI/MRA Scan ..... 14
  - Cerebral Angiogram ..... 15
- Treatment Options** ..... 16
  - Microsurgery ..... 16
  - Endovascular Surgery ..... 16
  - Stereotactic Radiosurgery ..... 17
- Inpatient Care** ..... 17
- Outpatient Care** ..... 18
- Emergency Care** ..... 19
- A Team Approach** ..... 19
- Physicians and Contact Information** ..... 20
  - Kevin Cockroft, M.D., M.Sc., FA.C.S., FA.H.A. .... 20
  - Robert Harbaugh, M.D., FA.C.S., FA.H.A. .... 20
  - Paul Kalapos, M.D., FR.C.P.(c) ..... 20
- Maps** ..... 21
  - University Physician Center (UPC) ..... 21
  - Main Hospital, first floor ..... 22
- Notes**



## Introduction

Penn State Milton S. Hershey Medical Center coordinates a comprehensive, multidisciplinary program for managing vascular diseases of the nervous system. Problems involving the blood vessels supplying the brain and spinal cord are treated using a variety of advanced methods. Penn State Hershey Neuroscience Institute is home to leading experts in the treatment of patients with occlusive cerebrovascular disease (a leading cause of stroke), cerebral aneurysms, and arteriovenous malformations of the brain and spinal cord. Our physicians and affiliates are available around the clock and provide individualized patient care using the latest techniques in microsurgery, endovascular surgery, and stereotactic radiosurgery.

The Medical Center has been designated as a Clinical Neuroscience Center of Excellence for its collaborative, multidisciplinary approach and commitment to the highest standards of neurological and neurosurgical patient care, education, and research. It has also earned the Gold Seal of Approval™ for stroke care. The Joint Commission on Accreditation of Healthcare Organizations awarded the Medical Center Primary Stroke Center Certification following an on-site review of the Penn State Stroke Center in September 2006. To earn the distinction, the center demonstrated that its stroke care program follows national standards and guidelines that can significantly improve outcomes for stroke patients.

1 This booklet provides an overview of the major neurovascular diseases, the methods we use to diagnose these diseases, and the latest, research-supported treatment options available at the Medical Center.

## Neurovascular Diseases

The following are some of the major neurovascular diseases treated at the Medical Center.

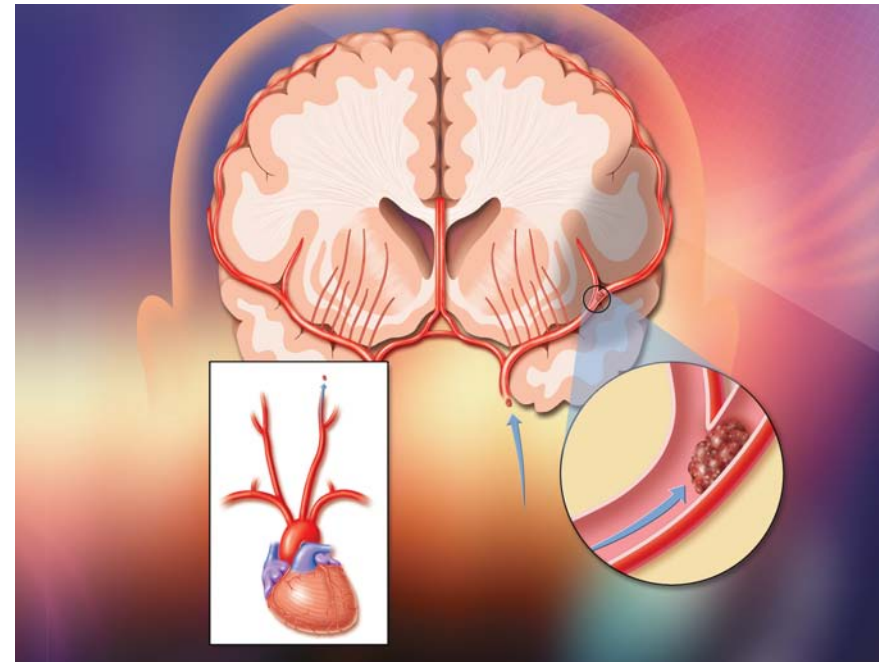
### STROKE

Stroke is the third leading cause of death and the number-one cause of adult disability in the United States. A stroke, sometimes referred to as a cerebrovascular accident (CVA), occurs when a blood vessel in or around the brain either bursts or becomes blocked. If the blood vessel bursts, it is called a hemorrhagic (bleeding) stroke. If the vessel is blocked, it is known as an ischemic stroke.

### Ischemic Stroke

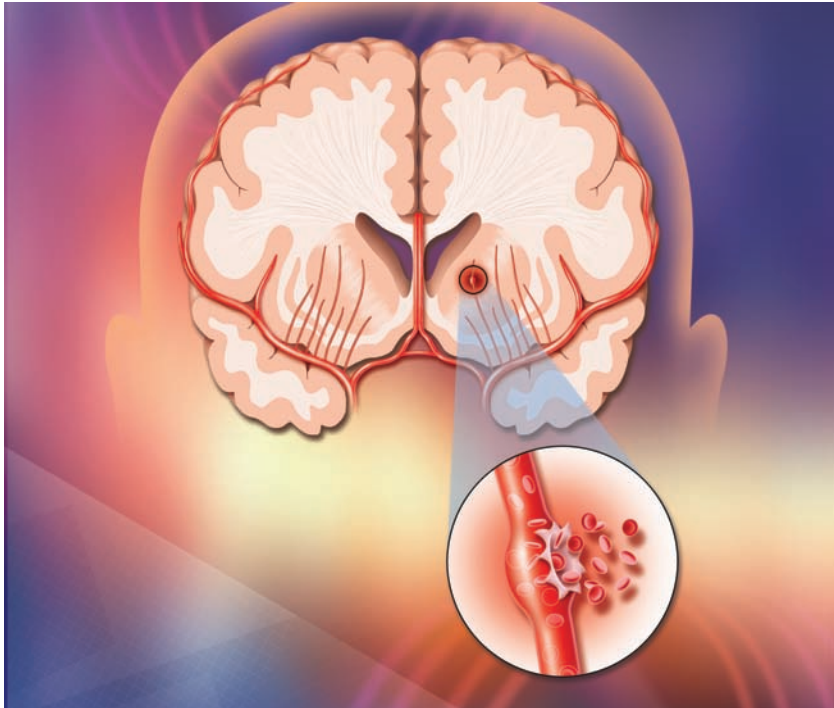
Ischemic stroke usually results when a blood clot restricts blood flow to the brain. A subcategory, cerebral thrombosis occurs when a brain artery becomes blocked by a blood clot developing directly in the artery. Such clots usually develop at sites of arteriosclerosis (hardening of the arteries). Another type of ischemic stroke, a cerebral embolism, occurs when a blood clot develops in another artery, or even the heart, and travels to the brain, where it becomes lodged in a brain artery and prevents continued blood flow. In either case, oxygen-rich blood is prevented from reaching areas of the brain beyond the blockage. When deprived of oxygen, the brain tissue quickly begins to die, resulting in a stroke (also known as a cerebral infarction).

2



## ■ Hemorrhagic Stroke

A hemorrhagic stroke results when a blood vessel in the brain bursts, preventing normal blood flow and oxygen supply. Subarachnoid hemorrhage and intracerebral hemorrhage are types of hemorrhagic strokes. A subarachnoid hemorrhage may be caused by the rupture of a cerebral (brain) aneurysm or an arteriovenous malformation (AVM). Intracerebral hemorrhage also can be caused by aneurysms and AVMs, as well as hypertension (high blood pressure) and other blood vessel abnormalities.



3

## ■ Carotid Artery Disease

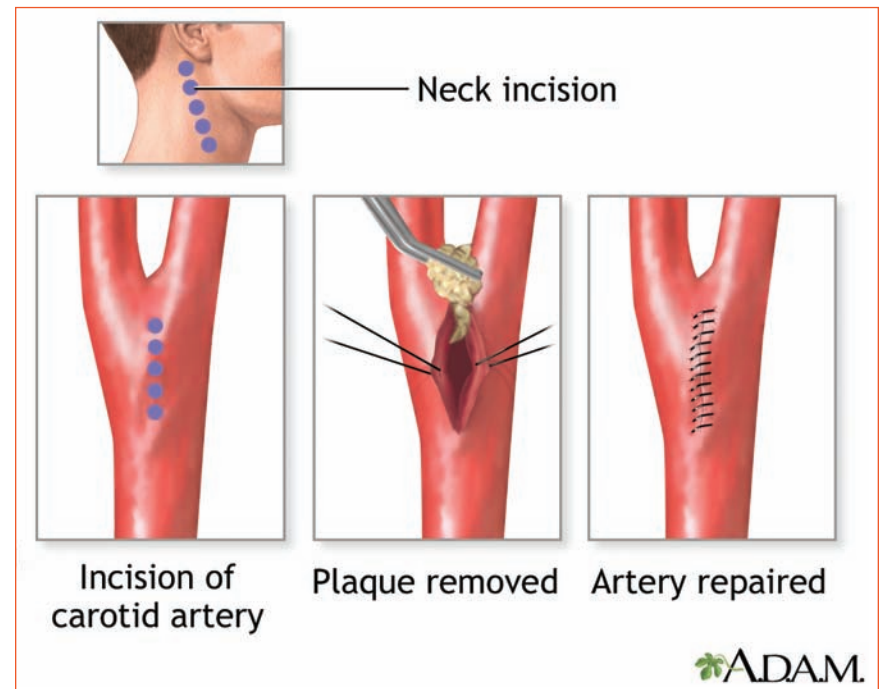
Located in the neck, the carotid artery is the main blood pipeline to the brain and a frequent site of blood clots. Carotid artery disease occurs when the carotid arteries become narrowed by arteriosclerosis or a buildup of plaque. Studies have shown that narrowing of the carotid arteries in such a manner increases a person's risk for stroke.

## STROKE PREVENTION

Steps can be taken to prevent stroke by lowering fat and cholesterol intake, quitting smoking, and exercising regularly. In certain patients where the arteries feeding the brain are severely narrowed by arteriosclerosis, a surgical procedure can be performed to clean out the artery and thereby reduce the risk of future stroke. When this surgery is performed on the carotid artery, it is called a carotid endarterectomy. Blocked arteries also may be opened from inside the blood vessel using a balloon and a stent. When this procedure is performed on the carotid artery, this is called carotid angioplasty and stenting.

## ■ Carotid Endarterectomy

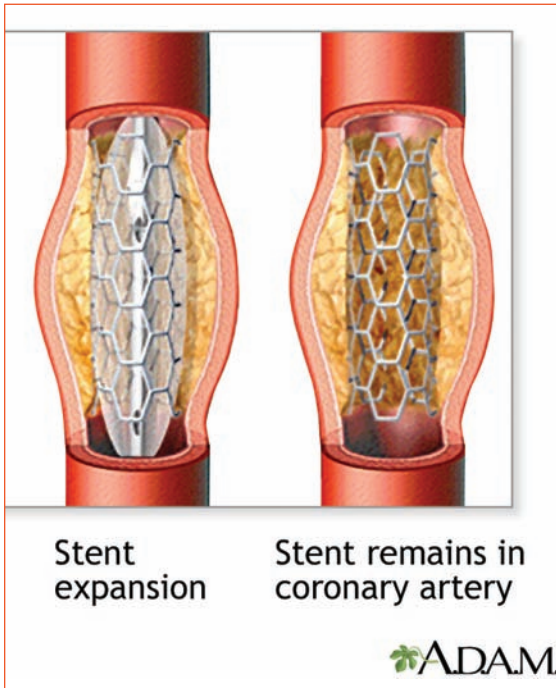
Carotid endarterectomy involves surgically cutting plaque out of the carotid artery. It is the most common surgical procedure performed for stroke prevention. Our neurosurgeons at the Medical Center have received specialized training and experience in this procedure. The majority of these procedures are performed under regional anesthesia (the area of the operation is made numb with an injection so patients are comfortable). Since patients are awake, they are less likely to suffer side effects to their heart or lungs from the anesthesia, and overall recovery is faster. Most patients will leave the hospital the next day.



4

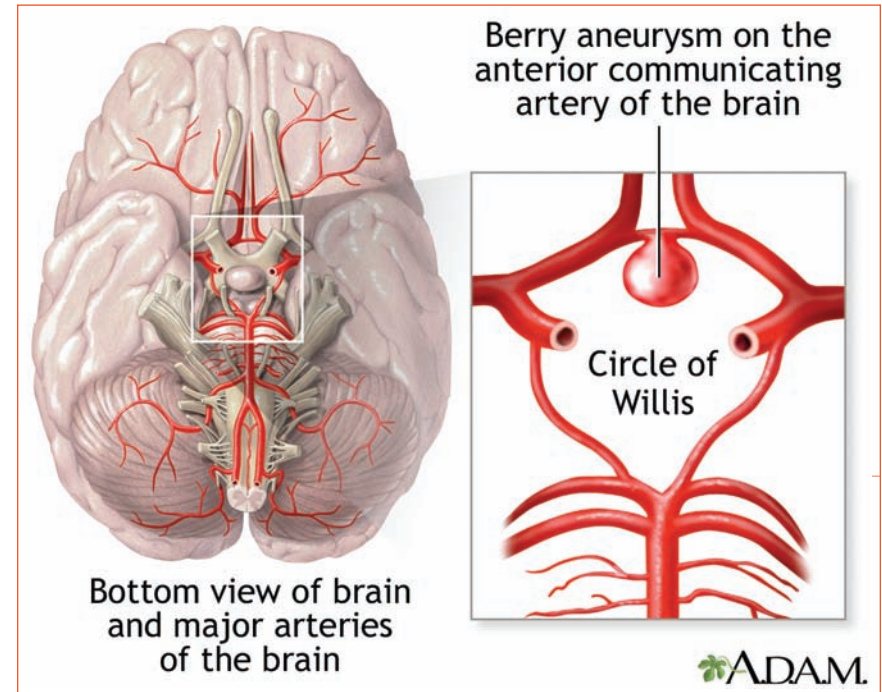
## Carotid Angioplasty and Stenting

Carotid angioplasty is a technique that uses a balloon and a stent (a mesh-like tube) to prop open a narrowed carotid artery from inside the blood vessel. A catheter is inserted into the femoral artery in the groin area through a small (1/4-inch) incision. The catheter is guided up to the carotid artery, and a balloon is passed through the catheter to the blockage. The balloon is inflated to open up the blockage and a stent is inserted to keep the artery open. The procedure is performed while the patient is awake, and most patients will go home the next day.



## CEREBRAL ANEURYSM

Cerebral aneurysms are abnormal bubbles or blisters on the blood vessels (usually arteries) in and around the brain. Cerebral aneurysms are estimated to be present in about 5 percent of the general population, and 20 percent of aneurysm patients may actually have more than one aneurysm. Also known as berry aneurysms, most brain aneurysms are sporadic, occurring without any particular cause or reason. Although the exact cause of brain aneurysms is unknown, both smoking and high blood pressure (hypertension) have been linked to the development of aneurysms. Aneurysms are associated with other brain blood vessel problems, including arteriovenous malformations (AVM) and moyamoya disease. Some patients with rare diseases, such as polycystic kidney disease, fibromuscular dysplasia, connective tissue disorders, and coarctation of the aorta aneurysms also may be prone to developing aneurysms. Many physicians recommend that patients with these disorders or with a family history of cerebral aneurysms (two or more first-degree relatives in the same family) undergo noninvasive screening.

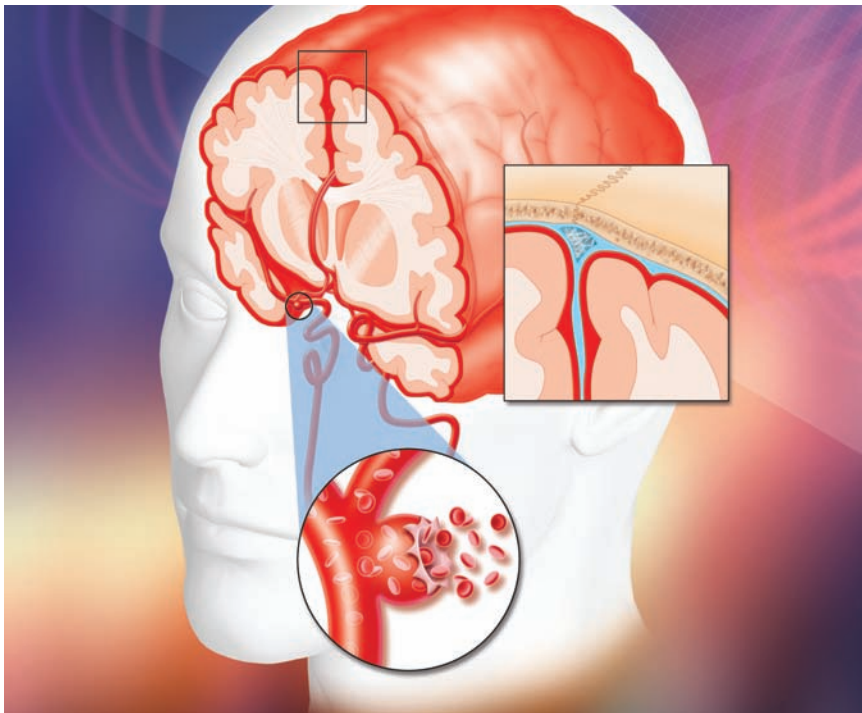


## Stroke Treatment

When ischemic stroke occurs, the Medical Center's Department of Neurology treats patients with the latest medications to dissolve blood clots, as well as with experimental treatments that attempt to preserve at-risk portions of the brain early in the development of a stroke. In addition, advanced procedures are available to provide acute stroke treatment from within the blocked artery itself. In these procedures, a catheter is used to locate the blocked artery. Clot-busting drugs can then be given directly to the site of blockage, or a corkscrew-like device can be used to pull out the clot.

## Subarachnoid Hemorrhage

Subarachnoid hemorrhage (SAH) simply means bleeding in the space around the brain where cerebrospinal fluid (CSF) circulates and where the major blood vessels are located. SAH is the most common problem associated with cerebral aneurysms. Severe headache is the most frequent symptom of spontaneous SAH. Patients will often describe it as the worst headache of their lives. While the overall aneurysm rupture rate is rather low (1-2 percent per year), the death rate after a hemorrhage is high. About half of those who suffer a cerebral hemorrhage will die within thirty days. Of those who survive, about half suffer significant disability. Besides bleeding, aneurysms also can cause problems by putting pressure on other important nearby structures.



## Hydrocephalus and Vasospasm

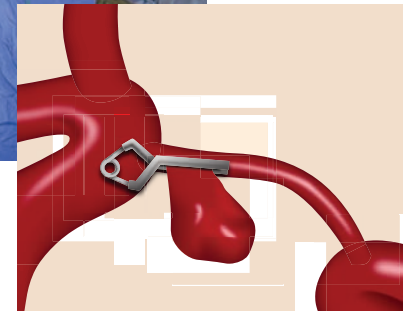
Rupture is the most feared aneurysm complication. Those who survive the initial rupture may face other problems, such as hydrocephalus and vasospasm. Hydrocephalus, sometimes called “water on the brain,” occurs when blood around the brain blocks the normal pathways of cerebrospinal fluid circulation and absorption. Vasospasm is the name given to the narrowing or spasm that occurs in some blood vessels during the days after subarachnoid hemorrhage. Severe vasospasm can lead to a stroke, as blood flow to a part of the brain becomes blocked.

## ANEURYSM TREATMENT

Because of the many problems associated with subarachnoid hemorrhage, the major focus of aneurysm treatment is on eliminating the aneurysm before it has a chance to burst. When early elimination is not possible, the aneurysm is usually closed off as soon as possible after the initial bleeding. In this situation, the aneurysm is treated to prevent rebleeding and to allow effective treatment of the hydrocephalus and vasospasm that may occur later. The two major methods for aneurysm treatment are microsurgery and endovascular surgery.

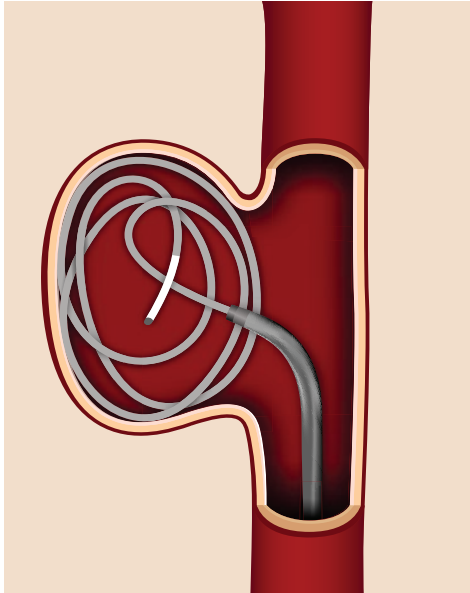
### Microsurgical Aneurysm Clipping

Microsurgery is a well-established method for treating brain aneurysms. It involves a surgical procedure called a craniotomy to open the skull and expose the aneurysm by slipping under and around the brain using delicate instruments and magnification with a high-powered microscope. Once the aneurysm is located, a titanium clip is placed across the base of the aneurysm. The clip stops blood from entering the aneurysm, thereby preventing it from bleeding. Microsurgery has existed for many years and is constantly advancing. Long-term follow-up of patients after microsurgical clipping shows an excellent success rate in preventing rebleeding. However, in some patients with severe bleeding, other medical problems, or aneurysms that are difficult to reach, the risks of surgical treatment may be quite high.



## Endovascular Aneurysm Surgery

Endovascular surgery for aneurysms is a newer, less-invasive technique for treating brain aneurysms. During endovascular surgery, a catheter is inserted into a patient's peripheral artery and navigated by an angiogram to the aneurysm's location. Once found, the aneurysm is then filled from the inside with tiny platinum coils. The coils react with the surrounding blood, causing it to clot, thereby obliterating the aneurysm. Endovascular treatment can be particularly effective for some aneurysms that are difficult to reach with open microsurgery. In addition, the risks of treatment in older patients, patients with major medical problems, and patients with severe bleeding may be much less than with traditional surgery. The short-term results using endovascular treatment for cerebral aneurysms are excellent. However, its long-term effectiveness is uncertain, and some aneurysms may re-grow even after complete treatment. For this reason, patients require close follow-up with repeated angiograms or Magnetic resonance angiography (MRA) studies. Occasionally, additional treatment may be necessary.



Depending on their size and location, as well as the health of the individual patient, some aneurysms may not require treatment. Alternatively, some complex aneurysms may require both major treatment techniques, and even other types of procedures. A treatment that is appropriate for one patient may not be appropriate for another. At the Medical Center, we have considerable experience and special training in both the microsurgical and endovascular aspects of aneurysm treatment. A team of physicians well-versed in all aspects of aneurysm management carefully develops an individualized treatment plan for each patient.

## VASCULAR MALFORMATIONS

Vascular malformations are abnormal tangles of blood vessels. When these tangles occur in the brain or spinal cord they are considered neurological problems. Four major types exist: arteriovenous malformations, cavernous angiomas, venous angiomas, and capillary telangiectasias. Other types of vascular malformations called dural arteriovenous fistulas involve abnormal connections of blood vessels in areas around the head, neck, and spine. Carotid-cavernous fistulas arise from abnormal connections between the arteries and veins behind the eye.

### Arteriovenous Malformations

Arteriovenous malformations (AVMs) consist of an abnormal network of arteries and veins that are directly connected without the usual intervening capillary network. They are thought to arise during fetal development and occur in less than 1 percent of the population. AVMs can cause problems by various means, but bleeding is the most common. Bleeding from an AVM is a type of stroke. Depending on the location and severity of the bleeding, patients may suffer significant neurological problems, such as numbness, weakness, or paralysis. AVMs can also cause seizures. When a patient's history or symptoms suggest an AVM, a CT or MRI scan will usually confirm the presence of the AVM and show its exact location. An angiogram can then be performed to give a more detailed picture of the structural characteristics of the AVM. The angiogram is essential to planning treatment for the AVM.

### AVM Treatment

Many vascular malformations treated at the Medical Center require more than one form of treatment. Often a combination of microsurgery, endovascular surgery, and stereotactic radiosurgery is required to achieve a complete cure. Complex patients are discussed by a multidisciplinary team of physicians highly experienced in all aspects of AVM treatment.

### Microsurgical Excision

Microsurgery uses traditional surgical techniques under high magnification and sometimes with computerized image guidance to remove the AVM. One of the major advantages of microsurgery is that it can result in an immediate cure. However, some lesions may be too large, too deep, or located in an area of the brain that is too risky for safe microsurgical excision. In such cases, other treatments may be necessary.

## ■ Embolization

In endovascular surgery, treatment is performed from within the affected blood vessel. Tiny microcatheters are navigated by a special angiogram up to the AVM. The AVM is then occluded from the inside using a process called embolization, whereby a special glue is injected into the abnormal blood vessels. Although effective in reducing the size of an AVM, endovascular embolization is rarely able to completely cure all but the smallest of AVMs. Endovascular therapy is usually combined with either microsurgery or stereotactic radiosurgery to give the best chance of a cure.

## ■ Stereotactic Radiosurgery

Stereotactic radiosurgery involves the delivery of a highly focused beam of radiation to the AVM. The two most common forms of radiosurgery are linear accelerator-based radiosurgery (also known as LINAC) and gamma ray-based radiosurgery (called Gamma Knife). Radiosurgery may be less risky than microsurgery for patients with AVMs that are deep or located in important brain

areas. However, it is difficult for radiosurgery to cure large AVMs (larger than one inch in diameter). With radiosurgery, cure is not immediate and may take up to two or three years. During this time, the patient may require follow-up tests and will still be at risk for problems from the AVM. For these reasons, radiosurgery is especially appropriate for small lesions that are located in or near critical brain areas or are very deep within the brain.

## ■ Cavernous Angioma

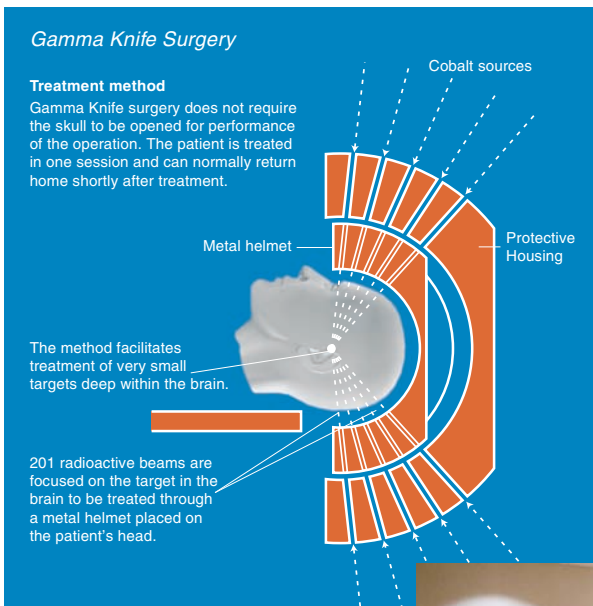
A cavernous angioma (also known as a cavernous malformation or cavernoma) is a type of vascular malformation. These lesions consist of a collection of slow-flow vessels under low pressure. These malformations are not visible on a conventional angiogram. For this reason, cavernous angiomas are often referred to as angiographically occult vascular malformations (AOVM). AOVMs may cause seizures and frequently bleed or leak blood. Severe or frequent bleeding may lead to the development of a neurological deficit, such as numbness, weakness, or paralysis.

Microsurgery is the treatment of choice for cavernous angiomas that are symptomatic and accessible. Removal of the cavernoma at surgery eliminates the risk of bleeding. In the case of epilepsy, surgery may reduce the severity of seizures or completely eliminate them. Since cavernous angiomas are not visible on an angiogram, endovascular embolization is not possible. Although somewhat controversial, stereotactic radiosurgery may have a role in the treatment of some deep or inaccessible lesions. At the Medical Center, we have considerable experience and special training in the treatment of AOVMs of the brain and spinal cord. Using specialized skull base microsurgical techniques and a computerized image guidance system, we are able to safely remove many challenging AOVMs that might previously have been left untreated.

## ■ Dural Arteriovenous Fistulas

Unlike AVMs and cavernomas, which are usually congenital (arising during development), dural arteriovenous fistulas (DAVFs) are usually acquired. These lesions consist of abnormal, direct connections between arteries external to the brain, such as those that supply the scalp or face and nearby veins. Patients with DAVF will often seek medical attention because they hear a wooshing sound that follows their heart beat. Occasionally, DAVFs can bleed, causing a stroke. DAVFs may be suspected on MRI or CT scans, but an angiogram is usually required to confirm the diagnosis. Depending on the severity of the patient's symptoms and the exact configuration of the DAVF on angiography, the lesion may or may not need to be treated. Similar to AVMs, DAVFs may be treated with endovascular glue embolization, microsurgical resection, stereotactic radiosurgery, or a combination of these. At the Medical Center, our physicians have experience and training in all major forms of treatment for DAVFs.

11



12



### ■ Carotid-Cavernous Fistula

Carotid-cavernous fistulas (CCFs) are yet another form of vascular malformation. CCFs are caused by an abnormal connection between the arteries and veins behind the eye. Patients will usually seek medical attention because of painful swelling of the affected eye. As the problem progresses, increased pressure behind the eye can lead to double vision, blurry vision, and even blindness, if left untreated. Typically, CCFs are treated with endovascular embolization or surgical occlusion. At the Medical Center, we use a multidisciplinary approach, including neurosurgeons, neuroradiologists, and neuro-ophthalmologists to evaluate and treat these complex lesions.

## Diagnostic Testing

The Medical Center's neuro angiography suite is equipped with the latest state-of-the-art technology. Angiograms are performed on a Siemens AXIOM Artis™, which allows physicians to obtain optimal image quality at a significantly reduced radiation dose. This machine, the first of its kind in central Pennsylvania, uses flat panel technology to produce crystal clear images. The equipment is even able to produce CT scan images, thus allowing for detailed testing without the patient ever having to leave the room. The following are tests commonly used in the diagnosis of neurovascular disease.

13

### ■ Carotid Duplex Scanning

Carotid duplex scanning is a type of ultrasound that uses sound waves to look inside the carotid artery. A technician places a plastic probe on the patient's neck and moves it back and forth, generating pictures of the carotid artery and the blood flow within it. Both carotid arteries are usually studied, regardless of the side on which a problem is suspected allowing the radiologist to compare the two sides. The duplex scan can tell if the carotid is narrower than normal or if it is completely blocked. Duplex scanning provides basic information at a relatively low cost. However, since carotid duplex scanning is a screening test, abnormal findings may need to be confirmed with other studies, such as magnetic resonance imaging (MRI), computed tomographic angiography (CTA), or catheter angiography.

### ■ CT Scan

A computed tomography (CT) scan is a common radiological study that uses a computer and multiple X-rays to generate pictures of internal body structures. A routine scan of the head takes only a few minutes and is not painful. Occasionally, an injection of contrast dye may be given to help differentiate between different structures within the skull and brain. In some instances, the study may be focused on the blood vessels of the head and neck to provide detailed information regarding blood vessel abnormalities. This study, which requires the use of contrast dye, is called a computed tomographic angiogram (CTA).



14

### ■ MRI and MRA Scans

Magnetic resonance imaging (MRI) utilizes a powerful magnet to produce extremely detailed pictures of the desired portion of the body. A scan of the brain usually takes several minutes longer than a CT scan, but the images obtained are much more detailed. The MRI scanner is a noisy machine, and sometimes people who are sensitive to tight spaces may become uncomfortable, but the scan itself is not painful. Like a CT scan, some MRI studies may require an injection of contrast dye. Magnetic resonance angiography (MRA) uses the same technology as MRI, but instead of producing pictures of solid organs, an MRA creates pictures specifically of blood vessels (arteries).

## ■ Cerebral Angiogram

Although MRA can provide a rudimentary picture of the blood vessels of the head and neck, the details are usually not sufficient in cases of an AVM or aneurysm. In such instances, a cerebral angiogram may be required. During an angiogram, a catheter is inserted into a peripheral artery (usually in the upper leg/groin area) and navigated to the neck or head from within the blood vessels. Once the catheter is in position, contrast dye is injected, and X-rays are taken. The result is a detailed picture of the network of vessels that supply blood to the brain.

Angiograms are performed in the hospital, and a complete brain angiogram may take more than an hour. Patients may be given medication for comfort, but most patients will not be completely asleep for the procedure. When the actual X-rays are being taken (a small portion of the time), the patient will be asked to lie extremely still. After the study is completed, the catheter will be removed, and the hole in the artery where the catheter entered will be closed. The hole will usually seal with about twenty minutes of direct manual pressure. However, this procedure requires the patient to remain in bed for approximately six hours to prevent bleeding. To avoid this, a closure device, or plug, may be used to seal the hole. Use of such a device will often allow the patient to be out of bed in about two hours.

Angiograms are usually very safe. However, because an angiogram involves putting a catheter into blood vessels that directly supply blood to the brain, there is a small risk of a stroke and/or damage to the blood vessels. A doctor will discuss the risks of the procedure before patients are asked to sign a consent form.



## Treatment Options

### ■ Multidisciplinary Treatment

Many of the neurovascular cases seen at the Medical Center require more than one form of treatment. As such, our physicians employ a multidisciplinary approach to the evaluation and treatment of patients. Microsurgery, endovascular surgery, and stereotactic radiosurgery are the most common treatments used. To create a comprehensive treatment plan, complex cases are reviewed at a multidisciplinary conference with professionals from all major treatment areas. The following is an overview of the major treatment options available.

### ■ Microsurgery

Surgery is the traditional manner by which most neurovascular lesions are treated. Today many advances in surgical techniques, including the use of powerful microscopes with intense illumination, fine micro-instruments, and intraoperative computer-assisted localization, have led to surgical successes in more complex lesions. At the same time, additional advances in the intraoperative monitoring of patients have helped make these complicated procedures safer. Occlusive cerebrovascular disease also may be treated surgically, either directly or through brain bypass operations. Penn State neurosurgeons use the latest techniques in microsurgery, along with state-of-the-art computer-guided localization and sophisticated intraoperative neurological monitoring to achieve the best possible surgical outcomes.

### ■ Endovascular Surgery

Endovascular surgery, also known as endovascular neurosurgery or interventional neuroradiology, involves the use of catheters, navigated through a patient's blood vessels by X-ray guidance, to locate and treat abnormalities of nervous system blood vessels. Procedures are usually performed by a specially trained neurosurgeon or neuroradiologist. Endovascular techniques are available to treat brain aneurysms, vascular malformations of the brain and spinal cord, and blockages of brain blood vessels. Many brain aneurysms may be treated by placing platinum coils into the aneurysm from inside the blood vessel, causing the aneurysm to clot off. Vascular malformations of various types also may be treated with injections of "super glue" from within a feeding blood vessel. Blocked blood vessels can sometimes be opened with special clot-busting medications or clot-retrieval devices. Narrowed arteries can be dilated using balloons and stents. Our physician staff has extensive experience and specialized, advanced training in neuroendovascular procedures. Our endovascular team has access to the latest sophisticated technology and equipment necessary to perform these cutting-edge procedures.

## ■ Stereotactic Radiosurgery

Stereotactic radiosurgery involves the delivery of a focused beam of radiation to a specific target area. Gamma Knife surgery, one of the most common forms of radiosurgery, uses gamma rays to target the area to be treated. Radiosurgery is used to treat certain types of vascular malformations, including AVMs and cavernous hemangioma. Radiosurgery also may be used to treat certain types of brain tumors, as well as other neurological disorders, such as trigeminal neuralgia (tic doloureux). At the Medical Center, our physicians have extensive experience using the Gamma Knife to treat all of these diseases.

## Inpatient Care

The diagnostic tests described earlier can usually be performed on an outpatient basis. With the exception of Gamma Knife radiosurgery, most of the major treatment procedures require admission to the hospital. Surgical procedures are performed in the main operating room, located on the second floor of the main hospital. Endovascular procedures are performed in the Neuroangiography Suite on the ground floor of the hospital. The majority of patients undergoing these procedures will be admitted to the Neuroscience Intensive Care Unit (ICU) or the Neuroscience Intermediate Care Unit (IMCU) on the fourth floor in the south wing of the main hospital.

17 After leaving the ICU or IMCU, most neurovascular patients will be transferred to the Inpatient Neuroscience Unit on the same floor. Gamma Knife procedures are performed as an outpatient in the Image Guided Treatment Center located in the South Annex of the main hospital. Within the last few years, we have added a new 16-bed Neuroscience Intensive Care Unit (NSICU) and a 15-bed Neuroscience Intermediate Care Unit (NSIMC). This dedication to neuroscience patients has allowed us to develop the neuroscience nursing expertise that is needed to provide quality care to our patients.



## Outpatient Care

In Spring 2008, the Medical Center opened a new outpatient care center that combines multiple specialties, including neurovascular services, in a single location. The center is designed to serve 150,000 patients a year.

The two-story, 165,000 square foot facility is home to integrated outpatient services for neurology, neurosurgery and orthopaedics; outpatient physical, occupational and speech therapies, rehabilitation and sports medicine; the Penn State Hershey Breast Center; and state-of-the-art imaging services including MRI and CT.

This new facility provides increased convenience and comfort for patients with a heightened level of collaboration between many different clinical services, providing patients with comprehensive care from some of the nation's finest physicians and surgeons, all under the same roof.

We are also pleased to announce that the newly formed Clinical Neuroscience Institute will combine the departments of Neurology, Neurosurgery, and Psychiatry with the divisions of Neuroradiology, Neuropathology, Neuroanesthesiology, and Neuro-Ophthalmology to create comprehensive service lines for all patients with neurological and neurobehavioral disorders. This type of interdepartmental collaboration will ensure that our patients get the most complete, appropriate, and timely care available anywhere.



## Team Approach

While in the hospital, patients will receive care from a dedicated, multidisciplinary team, including the following:

**Physicians**—neurosurgeons, neuroradiologists, neurologists, and neuroanesthesiologists, as well as the patient's primary care physician, when possible

**Nurses**—R.N.s and L.P.N.s assess, assist in, and coordinate patient needs and plans of care, as well as administer treatments and provide patient/family instruction

**Nursing Assistants**—provide personal care and hygiene

**Physical, Occupational and Speech Therapists**—provide individualized rehabilitation treatment

**Medical Social Worker**—offers support to patients and families; works to coordinate appropriate community resources and discharge planning

19 **Chaplain Services**—offer spiritual support to patients and families

**Case Managers**—oversee hospitalization and coordinate with insurance payors; work to ensure follow-up arrangements, such as home care

**Dietitian**—assists with proper design of nutritional and caloric intake

### Emergency Care

The Medical Center is the only tertiary-care, academic medical center in central Pennsylvania. As a result, patients with life-threatening neurovascular emergencies are often transferred to the Medical Center from other hospitals for specialized care. Penn State's Life Lion helicopter provides 24-hour emergency service for many of these patients. Other critically ill patients may come to the hospital directly through the emergency department.



## Principal Physicians

■ **Kevin M. Cockroft, M.D., M.Sc., F.A.C.S., F.A.H.A.**  
*Director, Neurovascular Services*



Dr. Cockroft is an associate professor of neurosurgery and radiology. He received his medical degree from Cornell University and his residency training at The New York Presbyterian Hospital-Cornell Medical Center. Dr. Cockroft completed fellowship training in open neurovascular surgery at Stanford University and endovascular neurosurgery (interventional neuroradiology) at Thomas Jefferson University. His clinical interests include brain aneurysms and subarachnoid hemorrhage, as well as AVMs of the central nervous system and occlusive cerebrovascular disease. Dr. Cockroft's research interests include outcome and risk factor analysis for vasospasm after subarachnoid hemorrhage and mechanisms of cerebral vasospasm.

■ **Robert H. Harbaugh, M.D., F.A.C.S., F.A.H.A.**  
*Chair, Department of Neurosurgery*



Dr. Harbaugh is a professor of neurosurgery and chair of the Department of Neurosurgery at Penn State College of Medicine. He received his medical degree from Dartmouth University and completed his residency training at the Dartmouth Hitchcock Medical Center. Dr. Harbaugh's clinical interests include occlusive cerebrovascular disease, brain aneurysms, and AVMs. He is internationally known for his expertise in performing carotid endarterectomy under regional anesthesia (while the patient is awake). His research interests include clinical outcomes after neurosurgical procedures and the effects of aneurysm morphology on rupture risk.

■ **Paul Kalapos, M.D., F.R.C.P.(c)**  
*Chief, Interventional Neuroradiology*



Dr. Kalapos is an assistant professor of radiology and neurosurgery. He received his medical degree from McGill University and completed his residency training at the University of Ottawa. Dr. Kalapos completed fellowship training in neuroradiology and interventional neuroradiology at New York University Medical Center. His clinical interests include brain aneurysms and vascular malformations, occlusive cerebrovascular disease, and minimally invasive treatments for degenerative spinal disorders. Dr. Kalapos' research interests include imaging and measurement of blood flow in ischemic cerebrovascular disease and noninvasive imaging of cerebrovascular disease.

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## Contact Information

For a new patient appointment, please call:  
717-531-8887 or 800-243-1455

For questions or general information please contact:  
Kevin M. Cockroft, M.D., M.Sc., F.A.C.S.  
Director, Neurovascular Services  
717-531-8807 or 800-243-1455

On the Web:  
[PENNSTATEHERSHEY.ORG/NEUROSCIENCE](http://PENNSTATEHERSHEY.ORG/NEUROSCIENCE)

For a stroke emergency, call 911

