



American  
Association of  
Neurological  
Surgeons

# STROKE

## PATIENT INFORMATION

This resource, developed by neurosurgeons, provides patients and their families trustworthy information on neurosurgical conditions and treatments.

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Stroke is an abrupt interruption of constant blood flow to the brain that causes loss of neurological function. The interruption of blood flow can be caused by a blockage, leading to the more common ischemic stroke, or by bleeding in the brain, leading to the more deadly hemorrhagic stroke. Ischemic stroke constitutes an estimated 87 percent of all stroke cases. Stroke often occurs with little or no warning, and the results can be devastating.

It is crucial that proper blood flow and oxygen be restored to the brain as soon as possible. Without oxygen and important nutrients, the affected brain cells are either damaged or die within a few minutes. Once brain cells die, they generally do not regenerate and devastating damage may occur, sometimes resulting in physical, cognitive and mental disabilities.

## Ischemic Stroke

- **Thrombotic (cerebral thrombosis)** is the most common type of ischemic stroke. A blood clot forms inside a diseased or damaged artery in the brain resulting from atherosclerosis (cholesterol-containing deposits called plaque), blocking blood flow.
- **Embolic (cerebral embolism)** is caused when a clot or a small piece of plaque formed in one of the arteries leading to the brain or in the heart, is pushed through the bloodstream and lodges in narrower brain arteries. The blood supply is cut off from the brain due to the clogged vessel.

## Transient ischemic attack (TIA)

This is a warning sign of a possible future stroke and is treated as a neurological emergency. Common temporary symptoms include difficulty speaking or understanding others, loss or blurring of vision in one eye and loss of strength or numbness in an arm or leg. Usually these symptoms resolve in less than 10 to 20 minutes and almost always within one hour. Even if all the symptoms resolve, it is very important that anyone experiencing these symptoms call 911 and immediately be evaluated by a qualified physician.

## Hemorrhagic Stroke

- **Subarachnoid Hemorrhage** is bleeding that occurs in the space between the surface of the brain and skull. A common cause of subarachnoid hemorrhagic stroke is a ruptured cerebral aneurysm, an area where a blood vessel in the brain weakens, resulting in a bulging or ballooning out of part of the vessel wall; or the rupture of an arteriovenous malformation (AVM), a tangle of abnormal and poorly formed blood vessels (arteries and veins), with an innate propensity to bleed.
- **Intracerebral Hemorrhage** is bleeding that occurs within the brain tissue. Many intracerebral hemorrhages are due to changes in the arteries caused by long-term hypertension. Other potential causes may be delineated through testing.

## Stroke Statistics

- Stroke is the third leading cause of death in the U.S.
- Statistics indicate that an estimated 135,592 people in the U.S. died from cerebrovascular disease in 2007.
- Of all strokes, 87 percent are ischemic, 10 percent are intracerebral hemorrhage and 3 percent are subarachnoid hemorrhage.
- While the incidence has increased, there has been a steady decline in mortality rates since 2002.
- Of the more than 795,000 people affected every year, about 610,000 of these are first attacks and 185,000 are recurrent.
- About 25 percent of people who recover from their first stroke will have another stroke within five years.
- Stroke is a leading cause of serious long-term disability, with an estimated 5.4 million stroke survivors currently alive today.
- In 2010, stroke cost about \$73.7 billion in both direct and indirect costs in the U.S. alone.

Source: American Heart Association (AHA), *Heart Disease and Stroke Statistics - 2010 Update*.

## Risk Factors

Although they are more common in older adults, strokes can occur at any age. Understanding the factors that increase your risk of a stroke and recognizing the symptoms may help you prevent a stroke. Receiving early diagnosis and treatment may improve your chances for complete recovery.

Controllable or treatable risk factors for stroke include:

- **Smoking:** You can decrease your risk by quitting smoking. Your risk may be increased further if you use some forms of oral contraceptives and are a smoker. There is recent evidence that long-term secondhand smoke exposure may increase your risk of stroke.
- **High blood pressure:** Blood pressure of 140/90 mm Hg or higher is the most important risk factor for stroke. It usually has no specific symptoms and no early warning signs. That is why it is important to have your blood pressure checked regularly. Controlling your blood pressure is crucial to stroke prevention.
- **Carotid or other artery disease:** The carotid arteries in your neck supply blood to your brain. A carotid artery narrowed by fatty deposits from atherosclerosis may become blocked by a blood clot. Carotid arteries are treated by neurosurgeons through carotid endarterectomy, a procedure in which an incision is made in the neck and plaque is removed from the artery; or carotid artery angioplasty and stenting, an endovascular procedure that requires no surgical incision in the neck.
- **History of TIAs:** About 30 percent of strokes are preceded by one or more TIAs that can occur days, weeks or even months before a stroke.

- **Diabetes:** It is crucial to control your blood sugar levels, blood pressure and cholesterol levels. Diabetes, especially when untreated, puts you at greater risk of stroke and has many other serious health implications.
- **High blood cholesterol:** A high level of total cholesterol in the blood (240 mg/dL or higher) is a major risk factor for heart disease, which raises your risk of stroke. Recent studies show that high levels of LDL (bad) cholesterol (greater than 100 mg/dL) and triglycerides (blood fats, 150 mg/dL or higher) increase the risk of stroke in people with previous coronary heart disease, ischemic stroke or TIAs. Low levels (less than 40 mg/dL) of HDL (good) cholesterol also may increase stroke risk. You can often improve your cholesterol levels by decreasing the salt and saturated fat in your diet. However, some people inherit genes associated with elevated levels of cholesterol. Although they may eat well and exercise, they still may have high cholesterol and must take medication to control it.
- **Physical inactivity and obesity:** Being inactive, obese or both can increase your risk of high blood pressure, high blood cholesterol, diabetes, heart disease and stroke. Getting 30 minutes of moderate exercise, five days a week can help reduce your risk of stroke. Check with your doctor first before starting any exercise program if you have any health problems or have been inactive.
- Recent research shows evidence that people receiving hormone replacement therapy (HRT) have an overall 29 percent increased risk of stroke, in particular ischemic stroke.

Uncontrollable risk factors include:

- **Age:** People of all ages, including children, have strokes. But the older you are, the greater your risk of stroke.
- **Gender:** Stroke is more common in men than in women. In most age groups, more men than women will have a stroke in a given year. However, women account for more than half of all stroke deaths. Women who are pregnant have a higher stroke risk. Some research has indicated that women may experience and interpret stroke symptoms differently than men, causing them to delay seeking medical care and contributing to their higher stroke mortality rates.
- **Heredity and race:** You have a greater risk of stroke if a parent, grandparent, sister or brother has had a stroke. African Americans have more than two times the risk of stroke compared to Caucasians, partly related to the prevalence of hypertension. Hispanics also have an elevated stroke risk.
- **Prior stroke or heart attack:** If you have had a stroke, you are at much higher risk of having another one. If you have had a heart attack, you are also at higher risk of having a stroke.

## Stroke Symptoms

The range and severity of early stroke symptoms vary considerably, but they share the common characteristic of being sudden. Warning signs may include some or all of the following symptoms:

- Dizziness, nausea or vomiting
- Unusually severe headache
- Confusion, disorientation or memory loss
- Numbness, weakness in an arm, leg or the face, especially on one side
- Abnormal or slurred speech
- Difficulty with comprehension
- Loss of vision or difficulty seeing
- Loss of balance, coordination or the ability to walk
- It is especially important to note that many strokes may cause an utterly painless loss of neurological function, leading to potential hesitation to call 911 or visit an emergency room.

## Stroke Effects

The effects of a stroke depend primarily on the location of the obstruction and the extent of brain tissue affected. One side of the brain controls the opposite side of the body, so a stroke affecting the right side will result in neurological complications on the left side of the body. A stroke on the right side may result in the following:

- Paralysis on the left side of the body
- Vision problems
- Quick, inquisitive or purposeless behavior
- Memory loss

A stroke on the left side may result in the following:

- Paralysis on the right side of the body
- Speech/language problems
- Slow, cautious behavior
- Memory loss

## Stroke Treatment

Rehabilitation following a stroke may involve a number of medical specialists; but the early diagnosis of a stroke, its treatment or its prevention, can be undertaken by a neurosurgeon. Rapid and accurate diagnosis of the kind of stroke and the exact location of its damage is critical to successful treatment. Technical advances such as digital imaging, microcatheters and other neurointerventional technologies, the use of the operating microscope (microsurgery) and the surgical laser have made it possible to treat stroke problems that were inoperable a few years ago.

### Ischemic Stroke Treatment

Ischemic stroke is treated by removing obstruction and restoring blood flow to the brain. The only U. S. Food and Drug Administration (FDA)-approved medication for ischemic stroke is tissue plasminogen activator (tPA), which must be administered within a three-hour window from the onset of symptoms to work best. Unfortunately, only 3- 5 percent of those who suffer a stroke reach the hospital in time to be considered for this treatment, and the actual use of tPA is considerably lower. This medication carries a risk for increased intracranial hemorrhage and is not used for hemorrhagic stroke.

### Emergency Surgical Stroke Treatment: Neurointerventional Procedures

Microcatheter-based surgical interventions for stroke may include the use of a small microcatheter, delivered through a larger guiding catheter inserted at the groin through a small incision. A microguidewire is used to navigate the microcatheter to the site of obstruction in the brain. Thrombolytic medication, such as tPA, can then be administered directly to the occluding thrombus. This kind of treatment, which delivers thrombolytic medication intraarterially, is more specific than IV (intravenous) tPA and consequently may require significantly lesser dosages of medication. The time limit to implement this type of intervention is also significantly (double) longer than that for IV TPA. Generally, only Comprehensive Stroke Care Centers offer this type of treatment.

### Clot Retrieval Devices

The Merci Retriever, approved in 2004 by the FDA, is a corkscrew- shaped device used to help remove blood clots from the arteries of stroke patients. A small incision is made in the patient's groin, into which a small catheter is fed until it reaches the arteries in the neck. At the neck, a small catheter inside the larger catheter is guided through the arteries into the brain, until it reaches the brain clot. A straight wire inside the small catheter pokes out beyond the clot and automatically coils into a corkscrew shape. It is pulled back into the clot, the corkscrew spinning and grabbing the clot. A balloon inflates in the neck artery, cutting off blood flow, so the device can pull the clot out of the brain safely. The clot is removed through the catheter with a syringe.

Penumbra is also a microcatheter-based system device, which works by an aspiration principle. It was approved by the FDA in 2008.

Stentriever devices are the newest generation of embolectomy devices for stroke. They are still in an investigative phase but work by breaking up the occluding clot, combined with aspiration or withdrawal.

### Medical Prevention

Medications used to help prevent stroke in high-risk patients (especially those who have experienced a previous TIA or ischemic stroke) fall into two major categories: anticoagulants and antiplatelet agents.

Anticoagulants thin the blood and prevent clotting. Heparin acts quickly and is given intravenously or subcutaneously (beneath the skin) while a patient is in the hospital. Slower-acting warfarin can be given orally and is used over a longer period. Because these drugs affect the blood's ability to clot, they require close monitoring by a physician.

Antiplatelet drugs prevent platelet aggregation. Platelets are specialized cells in the blood that initiate a healing process. Large numbers of platelets clump together to form a clot, which can sometimes block an artery or break loose, travel through the bloodstream and block a smaller artery. Antiplatelet drugs make platelets less sticky and less likely to form clots, reducing the risk of ischemic stroke in patients who have had TIA or prior ischemic stroke.

## Preventive Surgical Procedures

### Carotid Endarterectomy Surgery (Carotid Endarterectomy, CEA)

Patients will be given either a general or local anesthetic before surgery. In this procedure, the neurosurgeon makes an incision in the carotid artery in the neck and removes the plaque using a dissecting tool. Removing the plaque is accomplished by widening the passageway, which helps to restore normal blood flow. The artery will be repaired with sutures or a graft. The entire procedure usually takes about two hours. One may experience pain near the incision in the neck and some difficulty swallowing during the first few days after surgery. Most patients are able to go home after one or two days and return to work usually within a month. Patients should avoid driving and limit physical activities for a few weeks after surgery.

There are potential complications with carotid endarterectomy surgery, just as there are with any type of surgery. There is a 1-3 percent risk of stroke following surgery. Another fairly rare complication is the reblockage of the carotid artery, called restenosis. This may occur later, especially in cigarette smokers. Numbness in the face or tongue caused by temporary nerve damage is a possibility, but uncommon. This usually clears up in less than one month and most often does not require any treatment.

### Carotid Angioplasty and Stenting

An alternative, newer form of treatment, carotid angioplasty and stenting (CAS), shows some promise in patients who may be at too high risk to undergo surgery. Carotid stenting is a neurointerventional procedure in which a tiny, slender metal-mesh tube is fitted inside the carotid artery to increase the flow of blood blocked by plaques. Access is gained through a small (0.5 cm) groin incision, but

no incision is made in the neck. The stent is inserted following a procedure called angioplasty, in which the doctor guides a balloon-tipped catheter into the blocked artery. The balloon is inflated and pressed against the plaque, flattening it and reopening the artery. The stent acts as scaffolding to prevent the artery from collapsing or from closing up again after the procedure is completed.

There are several potential complications of endovascular treatment. The most serious risk from carotid stenting is an embolism caused by a disrupted plaque particle breaking free from the site. This can block an artery in the brain, causing a stroke. These risks are minimized using small filters called embolic protection devices in conjunction with angioplasty and stenting. There is also a slight risk of stroke due to a loose piece of plaque or a blood clot blocking an artery during or right after surgery. The risks are balanced against the advantages of a shorter occlusion time (10 seconds, as opposed to 30 minutes for endarterectomy), shorter anesthesia and a small leg incision.

Hyperperfusion, or the sudden increased blood flow through a previously blocked carotid artery and into the arteries of the brain, can cause a hemorrhagic stroke. Other complications include restenosis and short periods of medically treatable reduced blood pressure and heart rate. These risks are similar for CEA and CAS.

## Hemorrhagic Stroke Treatment

Hemorrhagic stroke usually requires surgery to relieve intracranial (within the skull) pressure caused by bleeding. Surgical treatment for hemorrhagic stroke caused by an aneurysm or defective blood vessel can prevent additional strokes. Surgery may be performed to seal off the defective blood vessel and redirect blood flow to other vessels that supply blood to the same region of the brain.

For a patient with a ruptured cerebral aneurysm, surgical elimination of the aneurysm is only the beginning. Intensive care recovery for the next 10-14 days is the rule, during which time a multitude of complications related to subarachnoid hemorrhage (SAH) can and do occur. At some time during that period (often immediately upon completion of surgery), cerebral angiography or a substitute study is done to document that the aneurysm has been eliminated. The first two to five days after SAH represent the greatest threat of brain swelling; at which time special measures (both medical and surgical) are used to diminish the effect of swelling on intracranial pressure. Near the end of this initial period, the risk period for delayed cerebral vasospasm begins and lasts the better part of the next 14 days. Intercurrent infections such as pneumonia are common, and hydrocephalus may develop.

### Surgery/Clipping

Prior to surgery, the exact location of the subarachnoid hemorrhage or aneurysm is identified through cerebral angiography images. An operation to "clip" the aneurysm is performed by doing a craniotomy (opening the skull surgically) and isolating the aneurysm from the normal bloodstream. In addition, a craniectomy, a surgical procedure in which part of the skull is removed and left off temporarily, may be done to help relieve increased intracranial pressure.

One or more tiny titanium clips with spring mechanisms are applied to the base of the aneurysm, allowing it to deflate. The size and shape of the clips is selected based on the size and location of the aneurysm. Clips are permanent, remain in place and generally provide a durable cure for the patient. Angiography is used to confirm exclusion of the aneurysm from the cerebral circulation and the preservation of normal flow of blood in the brain.

## Endovascular (Neurointerventional) Treatment

Neurointerventional procedures for cerebral aneurysm share the advantages of no incision made in the skull and an anesthesia time that is often dramatically shorter than for craniotomy and microsurgical clipping.

In endovascular microcoil embolization, a needle is placed into the femoral artery of the leg, and a small catheter is inserted. Utilizing x-ray guidance, the catheter is advanced through the body's arterial system to one of the four blood vessels that feed the brain. A smaller microcatheter is fed into the aneurysm, and once properly positioned, a thin wire filament or "coil" is advanced into the aneurysm. The flexible, platinum coil is designed to conform to the shape of the aneurysm. Additional coils are advanced into the aneurysm to close the aneurysm from the inside. This prevents flow of blood into the aneurysm by causing a clot to form on the inside.

Balloon-assisted coiling uses a tiny balloon catheter to help hold the coil in place. Although this has been shown in several studies to increase risks, ongoing innovations in this relatively new technology has helped improve its efficacy. Combination stent and coiling utilizes a small flexible cylindrical mesh tube that provides a scaffold for the coiling. Intracranial stenting and other innovations are quite new, and endovascular technology is in a constant state of development. These adjuncts allow coiling to be considered for cerebral aneurysms that may not have an ideal shape for conventional coiling.

## Stroke Rehabilitation

Recovery and rehabilitation are among the most important aspects of stroke treatment. As a rule, most strokes are associated with some recovery, the extent of which is variable. In some cases, undamaged areas of the brain may be able to perform functions that were lost when the stroke occurred. Rehabilitation includes physical therapy, speech therapy and occupational therapy. This type of recovery is measured in months to years.

- Physical therapy involves using exercise and other physical means (e.g., massage, heat) and may help patients regain the use of their arms and legs and prevent muscle stiffness in patients with permanent paralysis.
- Speech therapy may help patients regain the ability to speak.
- Occupational therapy may help patients regain independent function and relearn basic skills (e.g., getting dressed, preparing a meal and bathing).

## Conclusion

Modern treatments for ischemic and hemorrhagic stroke have reached an advanced state of development in the modern era of digital and device technology. Neurointerventional treatments enable surgical procedures in the brain without the need to open the skull surgically and provide excellent treatment alternatives for all forms of stroke and cerebrovascular disease. These developments are timely, occurring in an era when stroke incidence is on the rise as the population ages.

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