

# Stroke



National Institute of Neurological Disorders  
and Stroke  
National Institutes of Health

Hope Through Research

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# Table of Contents

What is a stroke? .....	1
What are the warning signs and symptoms for stroke? .....	2
What are common effects of a stroke? .....	3
Problems with muscle movement (motor sensory impairment).....	3
Problems with cognition, thinking, or memory	4
Problems with speaking or understanding speech.....	4
Problems with emotion .....	5
Problems with pain and sensation .....	5
What are the different types of stroke? .....	6
Ischemic Stroke .....	6
Hemorrhagic Stroke .....	8
What is a transient ischemic attack? .....	10
Who is at risk of stroke? .....	11
Women and stroke.....	12
Children and stroke .....	13
What are the risk factors for stroke?.....	14
Unmodifiable risk factors .....	14
Age.....	14
Gender .....	15
Family history .....	15
Race .....	16
The “Stroke Belt” .....	16
Prior stroke or heart attack.....	16

Modifiable Risk Factors .....	16
High blood pressure.....	17
Atrial fibrillation .....	18
Cholesterol levels .....	19
Diabetes .....	20
Smoking .....	21
Physical inactivity and obesity .....	21
Head and neck injuries.....	22
Drug abuse .....	22
How is stroke diagnosed? .....	23
How is stroke treated? .....	26
Ischemic stroke treatments .....	27
Medications .....	27
Surgical and Endovascular procedures ..	31
Stroke prevention .....	31
Clot removal .....	32
Hemorrhagic stroke treatments .....	33
Aneurysmal Subarachnoid Hemorrhage .	34
Intracerebral hemorrhage .....	35
Rehabilitation .....	37
What research is being done? .....	39
NIH StrokeNet .....	41
New, More Effective Treatments .....	41
How can I help with stroke research? .....	47
Where can I go for more information? .....	47

## What is a stroke?

A stroke is a brain attack—a sudden interruption of continuous blood flow to the brain—and a medical emergency. A stroke occurs when a blood vessel in the brain becomes blocked or narrowed, or when a blood vessel bursts and spills blood into the brain. Just like a heart attack, a stroke requires immediate medical attention.

Some brain cells die because they stop getting the oxygen and nutrients they need to function. Other brain cells die because they are damaged by sudden bleeding in or around the brain. Some brain cells die quickly but many linger in a compromised or weakened state for several hours. Stroke causes permanent brain damage over minutes to hours.

In stroke, “Time is brain,” meaning that the sooner treatment begins, the better. Knowing the signs of stroke and calling 911 immediately can help save a relative, neighbor, or friend. With timely treatment it is possible to save these cells and greatly reduce and reverse the damage.

Strokes can be prevented and treated. Making lifestyle changes and getting regular medical and prenatal care can help prevent stroke and significantly reduce the risk for other disorders such as dementia, heart disease, and diabetes.

## What are the warning signs and symptoms for stroke?

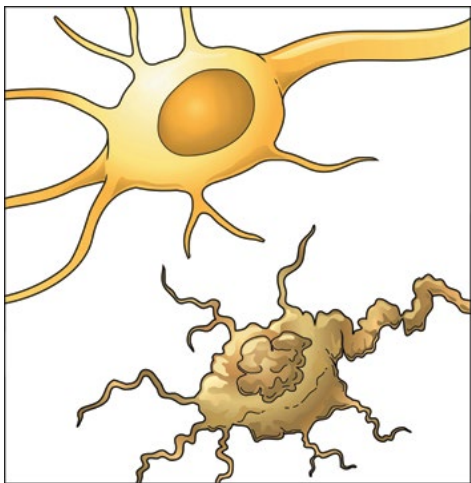
Stroke warning signs are clues the body sends when the brain is not receiving enough oxygen. The key to recognizing stroke symptoms is that they come on suddenly.

People who suffer a stroke may not realize what is happening to them or

mistakenly choose to ignore the signs, thinking the problem will pass. Even when people know there's a problem, they may not be able to call for emergency help on their own. The people around them might not know what is happening either, but they may recognize that something is wrong.

Call 911 immediately if one or more of the following symptoms occurs:

- sudden numbness or weakness of the face, arm, or leg, especially on one side of the body
- sudden confusion, trouble speaking or understanding
- sudden loss of vision or trouble seeing in one or both eyes
- sudden trouble walking, dizziness, loss of balance or coordination



When a stroke occurs, brain cells can die due to a lack of oxygen and the nutrients they need to function.

- sudden unusually severe headache with no known cause.

More rarely, people who may be having a stroke also may have disorientation or memory loss, nausea, dizziness, or vomiting.

Sometimes the warning symptoms may last only a few moments and then disappear. These signs may indicate that someone is having a minor stroke or a transient ischemic attack.

## What are common effects of a stroke?

The brain is nourished by one of the body's richest networks of blood vessels. A blockage or rupture in one of these blood vessels may occur in any area of the brain. Since each area is responsible for different functions, the effects of stroke may range from mild to severe disabilities depending on the type, severity, and location of the stroke. The symptoms may be temporary or permanent.

3

For example, the brain stem controls vital functions such as breathing, blood pressure, and heartbeat and connects the brain with the rest of the body. A stroke in the brain stem can be fatal or can leave someone in a "locked-in" state in which the person is paralyzed, cannot speak, and can only move the eyes up and down.

### **Problems with muscle movement (motor sensory impairment)**

A common after-effect of stroke is weakness (paresis) or paralysis (plegia). The paralysis or weakness may affect only the face, an arm, or a leg, or it may affect one entire side of the body and face. Movement problems can result from damage

to the part of the brain that controls balance and coordination. A person who has had a stroke may have problems with the simplest of daily activities, such as walking, dressing, eating, and using the bathroom. Some people with stroke also have trouble swallowing, called dysphagia.

### **Problems with cognition, thinking, or memory**

Stroke may cause problems with thinking, awareness, attention, learning, judgment, and memory. Some people with stroke have a “neglect” syndrome, which means that they have no knowledge of one side of their body (usually the left side of space), or one side of the visual field, and are unaware of the problem. A person with stroke may be unaware of his or her surroundings, or may be unaware of the cognitive, emotional, and/or behavioral problems that resulted from the stroke. Some people will experience a permanent decline in cognitive function known as vascular cognitive impairment (VCI). In its extreme, it includes vascular dementia, but it also refers to a gradual decline in mental function caused by multiple strokes, some silent (without noticeable symptoms), over time. VCI appears to primarily affect the brain’s executive function—the ability to plan activities from getting dressed in the morning to managing medications, finances, or negotiating a business deal. Controlling risk factors can reduce the risk of vascular cognitive impairment and dementia.

### **Problems with speaking or understanding speech**

People who have had a stroke often have problems speaking or understanding language. It is often accompanied by similar problems in reading and writing. In most people, language problems result



from damage to the left hemisphere of the brain and severe damage can result in a complete inability to speak or understand (aphasia).

Slurred speech due to weakness or incoordination of the muscles involved in speaking is called dysarthria and is a physical, not a language, problem. Dysarthria can result from any weakness or lack of coordination of the speech muscles and can arise from damage to either side of the brain. It is often associated with trouble swallowing, called dysphagia.

### **Problems with emotion**

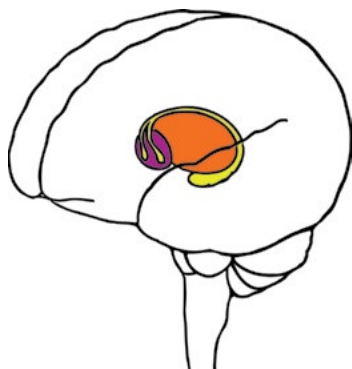
People with stroke may have difficulty controlling their emotions or may express inappropriate emotions in certain situations. Post-stroke depression, which commonly occurs in people with stroke, is a serious medical problem that can hamper recovery and rehabilitation and may even lead to suicide. Post-stroke depression can be treated with antidepressant medications and psychotherapy.

5

### **Problems with pain and sensation**

People may experience pain, uncomfortable numbness, or strange sensations after a stroke. These sensations may be due to many factors, including damage to the sensory regions of the brain, stiff joints, spastic muscles, or a disabled limb.

An uncommon type of pain resulting from stroke is called central stroke pain or central pain syndrome (CPS). CPS results from damage to an area of the



The thalamus is an area of the brain involved with sensory perception and movement.

brain called the thalamus, which is involved with sensory perception and movement. The pain is a mixture of sensations, including heat and cold, burning, tingling, numbness, and sharp stabbing and underlying aching pain. It is intense in the area affected by the stroke, such as the face, extremities or trunk on one side, and is made worse by movement and temperature changes, especially cold temperatures. Unfortunately, since most pain medications provide little relief from these sensations, there are very few treatments or therapies to combat CPS.

## What are the different types of stroke?

6

There are two main types of stroke. The most common type in the U.S., called an ischemic stroke, accounts for approximately 80 percent of strokes. The other kind, called a hemorrhagic stroke, accounts for the remaining 20 percent.

### Ischemic Stroke

An ischemic stroke occurs when the supply of blood to one or more regions of the brain is suddenly cut off or interrupted. It is similar to a heart attack, but it occurs in the brain and causes a lack of oxygen to millions of neurons and other brain cells fed by the blocked artery. It is most commonly caused by a blood clot or cellular debris (such as plaque—a mixture of fatty substances, including cholesterol) that blocks or plugs a blood vessel in the brain. Blockages that cause ischemic strokes stem from three conditions:

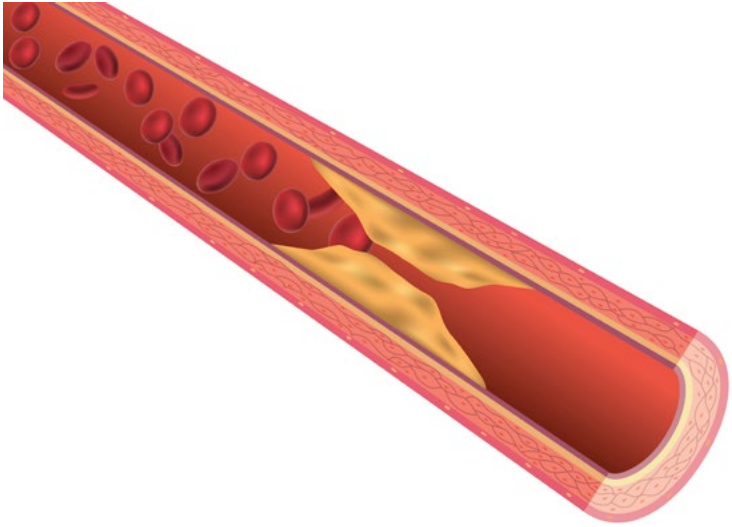
- a clot develops within a blood vessel of the brain and grows large enough to impair blood flow, called thrombosis

- a clot moves from another part of the body (such as the heart or a diseased artery in the chest or neck) into a narrower artery in the neck or brain, called embolism
- an artery in the brain or neck narrows, called stenosis.

Blood clots are the most common cause of artery blockage and brain infarcts (damaged or dead areas of brain tissue). Blood clotting is necessary and helpful because it stops bleeding and allows the body to repair damaged small blood vessels at the site of injury. However, blood clots that form in the heart or an artery leading to the brain or in a large vein that drains blood from the brain can cause devastating injury by blocking normal brain blood flow.

Arterial narrowing, also called stenosis, can also cause ischemic stroke. The most common cause of stenosis is atherosclerosis—a condition where deposits of plaque build along the inside of arteries, causing thickening, hardening, and loss of elasticity of artery walls. It is the same condition that leads to heart attack.

Narrowing of the small arteries in the brain is also a common cause of stroke in people with high blood pressure. The progressive scarring of the blood vessel wall is called arteriosclerosis and it causes small, usually multiple infarcts in deep regions of the brain. These vessels also supply blood to the “white matter,” which are the “wires” that connect the brain regions to each other or to the spinal cord. Arteriosclerosis is also thought to cause “diffuse white matter disease”—a common finding on MRI scans associated with damage to the wires, called axons, their insulating coating, called myelin, and leaky small blood vessels. Diffuse white matter disease increases the risk of developing



Atherosclerosis is a condition where deposits of plaque build along the inside of arteries, causing thickening, hardening, and loss of elasticity of artery walls.

8

**cognitive impairment with aging. Vascular cognitive impairment tends to interfere with attention and the ability to plan, organize, and multi-task.**

Acute ischemic damage can also provoke inflammation, swelling (called edema), and other processes that can continue to cause damage for hours to days after the initial insult. In large ischemic strokes, the swelling can cause the pressure inside the skull to rise to dangerous levels.

Immediately after an ischemic stroke, the brain usually contains an irreversibly damaged core of tissue and an area of viable but at-risk tissue. Restoring normal blood flow—a process called reperfusion—is essential to rescuing the tissue that is still viable. The longer reperfusion is delayed, the more cells will die.

### **Hemorrhagic Stroke**

In a healthy, functioning brain, neurons (brain cells) do not come into direct contact with blood. The blood-brain barrier, an elaborate meshwork of tightly

fitting cells that form the inside layer of tiny blood vessels called capillaries, regulates which parts of the blood can pass through to the brain cells and what substances can pass into the bloodstream.

When an artery in the brain bursts, blood gushes into or around the brain, damaging the surrounding tissue. This is called a hemorrhagic stroke. The blood that enters the brain increases the pressure inside the skull (called intracranial pressure) that can cause significant tissue damage. The mass of blood compresses the adjacent brain tissue, and the toxic substances in the blood mass further injure the brain tissue.

There are three types of hemorrhagic stroke, depending on where the bleeding occurs:

- a subarachnoid hemorrhage (also called subdural hemorrhage) involves rupture of a vessel on the surface of the brain and bleeding into the space between the brain and an envelope of tissue called the arachnoid layer
- a parenchymal or intracerebral hemorrhage involves bleeding directly into the brain tissue
- an intraventricular hemorrhage involves bleeding into or around the ventricles, the chambers in the brain that contain the cerebrospinal fluid that surrounds and bathes the brain and spinal cord.

Conditions such as chronic high blood pressure (hypertension) and cerebral amyloid angiopathy (a buildup of the protein amyloid on the inside wall of blood vessels) can cause blood vessels to burst. Irregularities in the brain's vascular system (the network of arteries, veins, and smaller blood vessels) can also cause hemorrhagic stroke.

- An aneurysm is a weak or thin spot on an artery wall. Over time, these weak spots stretch or balloon out. The thin walls of ballooning aneurysms can rupture, causing blood to gush into the space next to the brain and raise the intracranial pressure to dangerously high levels. Small cerebral aneurysms, less than 3mm in diameter, are common. They usually do not cause symptoms unless there is a family history of bleeding aneurysms. The risk of bleeding is increased if there is a family history of bleeding aneurysms, or if the aneurysms are large (greater than 7mm in diameter). In those instances, neurosurgical or intra-arterial aneurysm repair is considered.
- Arteriovenous malformations (AVMs) also increase the risk of hemorrhagic stroke. An AVM is an abnormal, snarled tangle of defective blood vessels within the brain that cause multiple irregular connections between the arteries and veins. The irregular connections allow arterial blood to travel directly to veins instead of first passing through a fine web of tiny capillaries. The blood flow through AVMs is exceedingly high and can cause the vessels to rupture.

In addition to a stroke, impaired blood supply through the brain's arteries and veins can cause venous infarctions, or areas of dead tissue.

## What is a transient ischemic attack?

A transient ischemic attack, or TIA, is a temporary cut-off of blood flow to the brain. A TIA occurs when blood flow to part of the brain is blocked, often by a clot, but then dissipates after a short time and the stroke symptoms go away. Any stroke damage from a TIA is typically temporary or

confined to a very small region, but a TIA is an important warning sign that a larger, more serious stroke could come soon. An important type of TIA due to narrowing of the carotid artery is a transient loss of vision in one eye.

A TIA—sometimes incorrectly referred to as a mini-stroke—starts just like any other stroke. Generally, the symptoms or deficits begin to disappear in less than 20 minutes, and often go away within an hour. However, these small strokes often indicate a high risk for a more serious stroke and an underlying condition that requires medical help. About 1 in 3 people who have a TIA will have a stroke sometime in the future, with the majority of those occurring within a year after the TIA. Additional factors increase a person's risk for a recurrent stroke. Because TIAs last for only a few minutes, many people mistakenly ignore them. However, taking action can save a life. Calling 911 as soon as symptoms appear can make the difference in avoiding lifelong disability.

11

## Who is at risk of stroke?

Each year nearly 800,000 Americans have a stroke, and about 600,000 are first strokes. Once a person suffers a first stroke, the risk of another stroke significantly increases. The risk of a recurrent stroke is greatest right after a stroke and decreases with time. In fact, about 25 percent of people who recover from their first stroke will have another stroke within 5 years,



Pregnancy-related stroke is more likely to occur in women who experience certain complications such as preeclampsia.

and approximately 3 percent of individuals with stroke will have another stroke within 30 days of their first stroke. Overall, one-third of recurrent strokes take place within 2 years of the first stroke.

Stroke occurs in all age groups, in both sexes, and in all races in every country. Stroke can even occur before birth, when the developing infant is still in the womb (a common cause of cerebral palsy).

## **Women and stroke**

Some risk factors for stroke apply only to women. These include pregnancy, childbirth, and menopause. These factors are tied to hormonal changes that affect women at different stages of life. In women of childbearing age, stroke risk is relatively low (with an annual incidence of 1 in 10,000). However, studies have shown that pregnancy increases that risk 3 times.

Several factors contribute to the increased risk of stroke during pregnancy.

- The activity of blood clotting proteins is naturally greater during pregnancy, increasing the chances of stroke for the mother. In some cases, clots form in the brain's large draining veins, leading to headache or seizure.
- Pregnancy-related stroke is more likely to occur in women who experience certain complications, such as infections or preeclampsia (high blood pressure with fluid retention), or who have other risk factors for stroke, such as high blood pressure or diabetes.
- Most maternal strokes occur during the post-partum period—the first few weeks after delivery. These strokes may be caused by a drop in blood volume or by the rapid hormonal changes that follow childbirth.



In the same way that hormonal changes during pregnancy and childbirth are associated with increased stroke risk, hormonal changes at the end of childbearing years—during menopause—also can increase the risk of stroke. Although hormone replacement therapy (HRT) may help some symptoms of menopause, studies have shown that HRT increases the risk of stroke.

## **Children and stroke**

Children have several unique stroke risk factors. The risk of stroke for children is actually highest during the perinatal period—which begins just before birth and ends a few weeks after. Boys and African American children are at a higher risk for stroke than other groups. Strokes can even occur in the womb.

Infants and children who have a stroke will experience symptoms that are similar to those in adults such as headache, hemiplegia (paralysis on one side of the body), and hemiparesis (weakness on one side of the body). However, children are more likely than adults to have other symptoms, including seizures, breathing problems, or loss of consciousness.

Risk factors for childhood stroke include congenital (present at birth) heart problems, head trauma, and blood-clotting disorders. An important risk factor for African American children is sickle cell anemia (a genetic blood disorder characterized by red blood cells that take on a sickle or crescent shape and block arteries). In addition to anemia, the disorder can cause joint pain, swollen spleen, frequent and severe infections, and narrowing of brain arteries.

Strokes that occur during the perinatal period may be caused by premature birth, maternal drug abuse,

and maternal health conditions such as infections, autoimmune disease, and preeclampsia.

The outcome of stroke in the very young is difficult to predict. A stroke during fetal development may lead to cerebral palsy. A stroke that occurs during infancy or childhood can also cause permanent disability. Generally, outcomes are worse in children under age one and in those who experience decreased consciousness or seizures.

Children who have a stroke generally recover better than adults after treatment and rehabilitation. This is due in part to the brain's plasticity, or its ability to reorganize, change, and adapt to deficits and injury, and to rewire itself to carry on necessary functions.

## What are the risk factors for stroke?

14

Some people are at a higher risk for stroke than others. Generally, stroke risk factors fall into two categories: unmodifiable or modifiable.

Unmodifiable risk factors—those that can't be changed or controlled—include age, gender, race or ethnicity, and family history. Modifiable risk factors and medical conditions, including high blood pressure, high cholesterol, and smoking, can be controlled with medical care or changed by the person at risk. Understanding the risk factors and working on them may help prevent a stroke.

### Unmodifiable risk factors

#### Age

Stroke affects people of all ages (including young adults, children, infants, and fetuses in the womb). However, stroke risk increases with age—the older you are, the more likely you are to have a stroke.

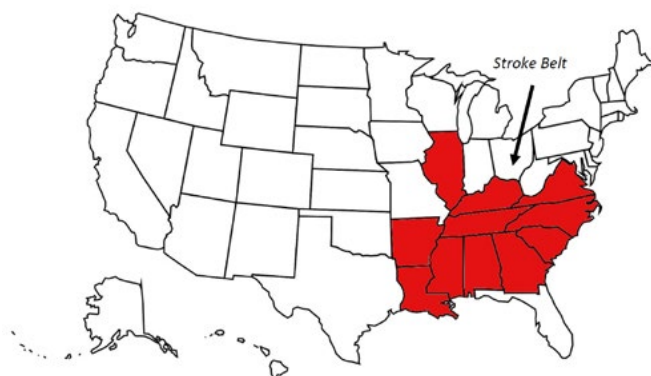
## Gender

Gender also plays a role in risk for stroke. Stroke is more common in men than women. Men have a higher risk of stroke in young and middle age, but rates even out at older ages, and more women die from stroke. Even though women have fewer strokes than men, women are generally older when they have their strokes and are more likely to die from them.

## Family history

Having a parent, grandparent, or sibling who has had a stroke puts a person at greater risk of stroke. The risk of stroke may be linked to certain genetic traits in some families. Several factors might contribute to the increased stroke risk. Some genetic mutations confer a strong risk of stroke, but weaker genetic contributions often come from members of a family who might have a genetic or inherited tendency for stroke risk factors, such as high blood pressure, diabetes, or heart disease. It is also possible that an increased risk for stroke within a family is due to modifiable behavioral factors such as an inactive lifestyle or poor eating habits that are due to habits or lack of education.

15



The “Stroke Belt” consists of eleven states—ten of which are in a cluster in the southeastern United States—that have unusually high stroke death rates.

## **Race**

The risk for stroke varies among different ethnic and racial groups. The incidence of stroke among African Americans and Hispanic Americans is almost double that of Caucasians. African and Hispanic Americans tend to have strokes at a younger age than Caucasians. The death rate from stroke is higher in African Americans than in Caucasians or Hispanics.

## **The “Stroke Belt”**

Eleven states—ten of which are in a cluster in the southeastern United States—have stroke death rates that are unusually high. These states—Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia—along with Indiana, are called the Stroke Belt. Several of these states also happen to have the highest age-adjusted death rates for cerebrovascular disease. This increased risk may be caused by geographic or environmental factors or by regional lifestyle differences, such as higher rates of cigarette smoking or a preference for salty, high-fat foods.

## **Prior stroke or heart attack**

Someone who has had a stroke or heart attack has a higher risk of having another one. Individuals who have had a heart attack also have a higher stroke risk.

## **Modifiable Risk Factors**

Modifiable risk factors are those that can be changed or controlled to prevent or reduce the risk of stroke. The most important modifiable risk factors for stroke are high blood pressure, heart disease, diabetes, and smoking. Others include

heavy alcohol use and high cholesterol. Control of these conditions is a highly effective population strategy and has led to a 70 percent decrease in stroke risk over the past 50 years.

Simple steps can help people reduce their risk of stroke, cognitive impairment, dementia, and heart disease later in life:

- Talk with a healthcare provider about the risk of stroke.
- Work with a provider to develop a plan to control blood pressure and other risk factors.
- Stick to the plan.

Making lifestyle changes can reduce a person's risk of stroke.

It is important that individuals should not stop taking their medications without first speaking with and getting approval from their healthcare provider. Stroke can be caused by people stopping their medication without medical guidance.

17

### **High blood pressure**

Hypertension or high blood pressure is the number one risk factor for stroke. For people with high blood pressure, the risk for stroke before age 80 is 2 to 4 times higher than the risk for those without high blood pressure. Hypertension promotes atherosclerosis and causes damage to blood vessels. Atherosclerosis is the major cause of blood vessel narrowing, leading to both heart attack and stroke. Early treatment is essential. Blood pressure should be checked regularly. Controlling blood pressure can decrease a person's risk for stroke and may prevent stroke and heart attack. Maintaining healthy blood pressure may also reduce the risk of other disorders later in life, including dementia and cognitive

**decline. Medications to treat high blood pressure (called antihypertensives) work by either by relaxing the blood vessels or decreasing blood volume.**

## **Can stroke be prevented?**

Stroke is preventable and treatable. A better understanding of the causes of stroke has helped people make lifestyle changes that have cut the stroke death rate nearly in half in the last 2 decades.

While family history plays a role in stroke risk, there are many risk factors that can be controlled.

- Proper prenatal care can prevent or treat high blood pressure during pregnancy and lower risk of stroke in the mother and complications during delivery.
- People who have high blood pressure should work with their doctor to control it. Managing high blood pressure is the most important thing one can do to avoid stroke. Controlling high blood pressure can also reduce the risk of dementia and cognitive decline in later life.
- People with high cholesterol should work with their doctor to lower it. High cholesterol is a major risk factor for heart disease, which raises the risk for stroke.
- People with diabetes should work with their doctor to manage it. Many people do not realize they have diabetes, which is a major risk factor for both heart disease and stroke.
- People who smoke should quit.
- People who are overweight should strive to maintain a healthy diet and exercise regularly.

## **Atrial fibrillation**

**The atria are the chambers that receive blood entering the heart. In atrial fibrillation the two upper chambers of the heart no longer beat; instead,**

the muscular walls show a fine wiggling movement called fibrillation. As a result, the atria don't push blood out to the two lower chambers of the heart. This leads to blood stagnation in the atria, and the formation of blood clots that can loosen and leave the heart and travel to the brain, causing an ischemic stroke. Atrial fibrillation is the most common heart arrhythmia affecting over 9 percent of people over age 65.

Medications called blood thinners (for example, warfarin or direct thrombin inhibitors) have been shown to substantially reduce stroke risk in people with atrial fibrillation. Surgical and endovascular procedures can sometimes stop atrial fibrillation from recurring or can be used to fill the part of the atria most likely to produce clots. People under age 60 with atrial fibrillation and no other risk factors may be prescribed aspirin.

19

### **Cholesterol levels**

Many people do not realize that high cholesterol contributes to stroke risk. Cholesterol—a waxy, fatty substance produced by the liver—is a vital body product. It contributes to the production of hormones such as vitamin D and is an essential part of the membranes that surround cells.

There are two kinds of cholesterol: high-density lipoprotein, or HDL, which is commonly called “good” cholesterol; and low-density lipoprotein, or LDL, which is usually referred to as “bad” cholesterol.

Most cholesterol in the body is LDL. Excessive LDL can cause cholesterol to build up in blood vessels, leading to stenosis and atherosclerosis. This excess—called plaque—blocks blood vessels and helps to form blood clots. A person's LDL level

ideally should be less than 130 mg/dL. [Cholesterol levels are measured in milligrams (mg) of cholesterol per deciliter (dL) of blood.] LDL levels between 130 and 159 indicate that a person may be at a slightly higher risk for atherosclerosis, heart disease, and stroke. A score over 160 puts a person at the greatest risk for a heart attack or stroke.

Certain levels of HDL cholesterol are beneficial and help to prevent stroke. Currently, an HDL score higher than 35 is considered good. Low HDL levels (less than 35 mg/dL) lead to an increased risk for heart disease and stroke.

Genetics also may play a role in high cholesterol levels. Hyperlipidemia (abnormally high levels of fatty materials called lipids) and hypercholesterolemia (too much cholesterol in the bloodstream) are inherited conditions that can cause high cholesterol.

20

A healthy diet and regular exercise are the best ways to lower total cholesterol levels. In some cases, doctors may prescribe cholesterol-lowering medication such as statin drugs. Statins significantly reduce stroke risk in most people with high cholesterol.

## **Diabetes**

Diabetes can damage the blood vessels in the brain and increase a person's risk for stroke. In diabetes, glucose (blood sugar) is not efficiently moved from the blood to the body's cells. Instead, it builds up in the blood, where it can damage the blood vessels and tissue that carry fluids (including blood) through the body. High blood pressure is common among people with diabetes and accounts for much of their increased stroke risk. The greatest modifiable risk factor for diabetes is obesity. The increase of obesity and diabetes in the U.S. is thought to be responsible



for the recent erosion of the decades-long progress in reducing stroke and heart attack.

Medications to control blood pressure and diabetes, dietary changes, and weight loss can lower a person's stroke risk. If blood glucose levels are high at the time of a stroke, then brain damage is usually more severe and extensive than when blood glucose is closer to normal. However, a recent clinical trial did not find benefit from aggressive use of insulin to control blood pressure in acute ischemic stroke. Controlling blood sugar does appear to reduce the risk of recurrent stroke.

### **Smoking**

Smoking by itself (without the presence of other risk factors) almost doubles a person's risk for ischemic stroke. Smoking promotes atherosclerosis and aneurysm formation and stimulates blood clotting factors. The risk for stroke decreases significantly 2 years after a person quits smoking; by 5 years, the risk decreases even further to the level of nonsmokers. Smoking also increases the risk of rupture and subarachnoid hemorrhage in people with cerebral aneurysms.

21

### **Physical inactivity and obesity**

Obesity—a medical condition in which a person has too much body fat—is associated with 3 other stroke risk factors: high blood pressure, diabetes, and heart disease. It clearly is a risk factor for stroke. While no studies have tested the effects of moderate exercise or weight loss on stroke risk, both tend to reduce high blood pressure and boost heart health. Always check with a physician before starting any exercise program.

## Head and neck injuries

Head injury or traumatic brain injury may cause bleeding within the brain leading to damage similar to that caused by a hemorrhagic stroke. Neck injury, when associated with spontaneous

tearing of the arteries caused by sudden and severe neck extension, neck rotation, or pressure on the artery, also is a contributing cause of stroke, especially in young adults. Neck calisthenics, “bottoms-up” drinking, extending the neck backwards over a sink for hair-washing in hair salons, and improperly performed chiropractic manipulation of the neck can also strain the arteries, possibly leading to stroke.



The risk for stroke decreases significantly 2 years after a person quits smoking; by 5 years, the risk decreases even further.

## Drug abuse

Drug abuse greatly increases the risk of stroke. Short- and long-term use of addictive drugs such as cocaine and amphetamine can damage blood vessel walls, causing them to rupture and bleed into the brain (hemorrhagic stroke). These and other drugs can also narrow the brain's blood vessels and stop blood flow, causing an ischemic stroke. Intravenous injection of drugs like heroin carries high risk of heart valve infection which can cause stroke. The risk of drug-related stroke increases each time the drug is used, especially if other risk factors are present.

## How is stroke diagnosed?

Doctors use several tools to help diagnose stroke quickly and accurately. The first step is a neurological examination, an observational evaluation of the nervous system. When a person suspected of having a stroke arrives at a hospital, a healthcare professional, usually a doctor or nurse, will carry out a detailed assessment of the person's signs and symptoms. They also will ask when the symptoms began. Because of the importance of early treatment, assessment can begin in the ambulance.

One test that helps doctors judge the severity of a stroke is the standardized NIH Stroke Scale, developed from research supported by the National Institute of Neurological Disorders and Stroke (NINDS). Healthcare professionals use the NIH Stroke Scale to measure neurological function and deficits by asking the person to answer questions and perform several physical and mental tests. This checklist of questions and tasks scores a person's level of alertness and ability to communicate and perform simple movements. Other scales that may be used include the Glasgow Coma Scale, the Modified Rankin Scale, and the Barthel Index. These scales can sensitively measure disabilities that result from stroke.

Healthcare professionals also use a variety of brain imaging techniques to assess stroke risk, diagnose stroke, determine stroke type (and the extent and exact location of damage), and evaluate individuals for clinical studies and best treatment.

- Computed tomography (CT) uses x-rays and a computer to create a series of cross-sectional images of organs, bones, and tissue. A plain CT of the head and brain is the most widely



Healthcare professionals use a variety of brain imaging techniques including CT and MRI to assess stroke risk, diagnose stroke, determine stroke type (and the extent and exact location of damage).

24

**used imaging procedure to rule out bleeding. CT is readily available at most hospitals and produces images quickly. Doctors must determine if there is any bleeding in the brain before giving certain medicines, such as thrombolytic therapy or t-PA (tissue plasminogen activator), which might increase bleeding and worsen a hemorrhagic stroke.**

**With the injection of a standard contrast agent (a dye) the CT scan can show the large blood vessels supplying the brain and determine if there is a blockage. The injection of the contrast agent also can be used to develop maps of brain blood perfusion that identify viable tissue from tissue that is already damaged. A NINDS-funded study recently demonstrated that this technique, called perfusion imaging, can identify some patients who will benefit from procedures to remove clot from the large vessels even many hours after stroke onset.**

- **Magnetic resonance imaging (MRI)** uses magnetic fields and radio waves to produce 3-dimensional detailed computerized images of bone structures, organs, nerves, and tissues, including brain tissue. One effect of ischemic stroke is the stagnation of water movement through the cells in injured brain tissue. Diffusion-weighted imaging (DWI, a special type of MRI) measures the diffusion (movement of molecules) of water in brain tissue, which changes during an ischemic stroke. DWI can diagnose ischemic stroke before it is visible on a non-contrast CT scan and is especially useful for detecting small areas of dead tissue caused by loss of blood supply. Using a contrast agent helps doctors see maps of brain blood perfusion that identify brain regions that have not yet been damaged and may be saved. In a recent NINDS-funded clinical trial, perfusion imaging was shown to identify some patients who can benefit from clot removal procedures even many hours after stroke onset.

25

Although MRI and CT are equally accurate for determining when hemorrhage (bleeding) is present, MRI provides a more accurate and earlier diagnosis of ischemic stroke, especially for smaller strokes and transient ischemic attacks, or TIAs. Also, MRI can be more sensitive than CT for detecting other types of neurological disorders that mimic the symptoms of stroke. However, MRI cannot be performed in people with certain types of metallic or electronic implants, such as pacemakers.

- **Catheter-based angiography** is a procedure used to determine blockages of the arteries or veins. A catheter is inserted into the arteries supplying the brain and a dye is injected to reveal the

site of blockage in an ischemic stroke or detect stenosis or vascular malformations (such as an aneurysm or arteriovenous malformation) that put a person at risk for stroke. Procedures to remove clot from large arteries also are performed with devices that can be inserted by catheters into the arteries and their placement is guided by catheter-based angiography.

Other tools include ultrasound to image atherosclerosis in the carotid artery and Doppler ultrasound to measure blood velocity in large blood vessels. Additionally, blood tests of the clotting system, an electrocardiogram (a display of the heart's electrical activity and rhythm ), a Holter monitor (which measures the EKG over days to identify episodes of atrial fibrillation), or a cardiac ultrasound searching for a clot in the heart or other cardiac abnormalities will be used to identify abnormalities that may have contributed to the stroke.

26

## How is stroke treated?

It is important to remember that, in stroke, “Time is brain.” A stroke can cause permanent damage within minutes to hours. Calling 911 immediately and arriving at the hospital in an ambulance can aid in stroke treatment and recovery.

Treatment following a stroke generally falls into three therapeutic approaches:

- emergency medical or surgical care given immediately after a stroke to minimize the extent of injury
- treatment to prevent a second or recurrent stroke
- rehabilitation to improve disabilities that result from stroke.

Treatment for ischemic stroke or a transient ischemic attack may include medicines and medical procedures. Treatment for hemorrhagic stroke involves finding and controlling the cause of bleeding. Remarkable progress has been made in acute stroke therapy, especially with stenting and devices for clot removal to restore blood flow in brain arteries (see Surgery section).

## Ischemic stroke treatments

### Medications

Medication or drug therapy is the most common treatment for ischemic stroke. The most effective kinds of drugs to prevent or treat acute (occurring in the past few hours) ischemic stroke are antithrombotics—blood-thinning medicines which include antiplatelet agents and anticoagulants—and thrombolytics (drugs that break up and dissolve existing clots).

27



In stroke, “Time is brain.” Calling 911 immediately and arriving at the hospital in an ambulance can aid in stroke treatment and recovery.

In treating a new stroke, every minute counts. Ischemic strokes can be treated by returning blood flow to the brain before the damage is complete—either by using intravenous thrombolytic drugs, which dissolve the blood clot that is blocking blood flow to the brain, or by placing a catheter into the blocked brain artery and removing the blockage. In all cases a person needs medical attention immediately after stroke symptoms start to be evaluated and receive treatment as fast as possible to preserve as much brain tissue as possible.

The body produces thrombolytic proteins, and some of these have been engineered into drugs. In the 1990s NINDS-funded research found that a thrombolytic drug known as t-PA (tissue plasminogen activator) can be effective if a person receives it intravenously (through a vein) within 3 hours after stroke symptoms have started. Study results show that individuals who were given intravenous t-PA were 30 percent more likely to have minimal or no disability three months after treatment. In 1996 this finding by the NINDS t-PA Study Group led to the first treatment approved by the U.S. Food and Drug Administration for acute ischemic stroke. Since thrombolytic drugs can increase bleeding, t-PA should be used only after the doctor is certain that the person has suffered an ischemic, and not a hemorrhagic, stroke. In more recent studies, scientists have identified conditions in which individuals may benefit from t-PA beyond the 3-hour window after stroke symptoms begin. Most clinicians now treat within a 4 ½-hour window.

Antithrombotics prevent the formation of blood clots that can become stuck in a brain artery and cause strokes. There are two kinds of blood-thinning medications—antiplatelets and anticoagulants used to prevent ischemic stroke.



- **Antiplatelet drugs prevent clotting by decreasing the activity of platelets, which are blood cells that promote healing by helping blood to clot. By reducing the risk of blood clots, these drugs lower the risk of ischemic stroke. Doctors prescribe antiplatelet drugs mainly to prevent stroke. The most widely known and used antiplatelet drug is aspirin. Other antiplatelet drugs include clopidogrel, ticlopidine, and dipyridamole.**
- **Anticoagulants lower the risk of stroke by reducing the clotting property of the blood. The most commonly used anticoagulants include warfarin, heparin, enoxaparin, and dalteparin. Some newer drugs, called direct thrombin inhibitors, have replaced warfarin in many cases because they do not require frequent blood testing or dietary modifications. Some examples of direct thrombin inhibitors include apixaban, edoxaban, and rivaroxaban.**

29

**Antiplatelet drugs and anticoagulants can help prevent a variety of potentially life-threatening conditions for which individuals with stroke are at risk, such as heart attack and blood clots in the lungs (pulmonary embolism) or in veins deep in the body—generally in the lower leg or thigh (deep vein thrombosis).**

**Another group of medications—called neuroprotectants—protect the brain from secondary injury caused by stroke. Although there are no approved neuroprotectants for use in stroke, many medicines have been and are being tested in clinical trials.**

## Other Early NINDS-funded Studies with Key Findings

Researchers have long been trying to determine if there is any benefit in giving antiplatelet drugs or anticoagulants during an ischemic stroke in addition to t-PA, or instead of t-PA (for people who are not eligible to receive t-PA). The purpose of one NINDS-sponsored trial—Trial of Org 10172 in Acute Stroke Treatment or TOAST—was to determine if stroke could be treated with a form of the anticoagulant drug heparin called Org 10172, which was less likely to cause bleeding. The study found that the drug produced no significant benefit. However, scientists were able to develop a set of guidelines—called the TOAST criteria—for defining different kinds of ischemic stroke. These guidelines now are widely used in other studies.

For many years, aspirin and warfarin were used to prevent stroke in people with atrial fibrillation—the most common heart condition that causes stroke. So, researchers sought to definitively determine if a daily regimen of aspirin or warfarin could benefit people at risk for ischemic stroke. Two NINDS studies showed that daily warfarin is best for people with atrial fibrillation who are over age 65 or who have additional risk factors. Results also showed that daily aspirin provides adequate protection against stroke among younger people (under age 60) with atrial fibrillation.

Two other NINDS-sponsored trials compared the effectiveness of daily warfarin and aspirin in people who did not have atrial fibrillation but who had experienced a prior stroke, and thus were at risk for another stroke. Both trials concluded that aspirin is equal to warfarin for reducing stroke risk in people without atrial fibrillation. A trial is now in progress to determine if anticoagulation with a direct thrombin inhibitor is more effective than antiplatelet therapy to prevent recurrent stroke in persons suspected of having atrial dysfunction.

## **Surgical and Endovascular procedures**

Brain blood vessels can be accessed by inserting catheters into large arteries in the leg and threaded into the brain blood vessels. This is the basis of catheter angiography, but it is also used to treat vascular abnormalities that cause stroke. Surgery can also be used to prevent or treat some types of stroke, or repair damage to the blood vessels, as well as to treat malformations in and around the brain.

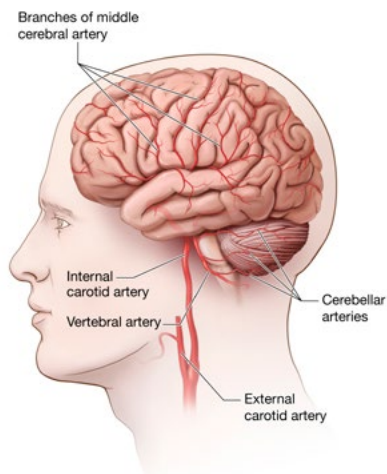
### **Stroke prevention**

Carotid endarterectomy involves surgical removal of obstructing plaque from the inside of a carotid artery which widens the artery. The carotid arteries, located in the neck, are the main suppliers of blood to the brain.

NINDS sponsored large clinical trials to test the effectiveness of carotid endarterectomy, which showed that carotid endarterectomy is safe and very effective in preventing stroke in people with carotid-associated TIAs and also somewhat effective for preventing stroke in most people without symptoms but who have more than 50 percent stenosis (narrowing of the carotid arteries). A NINDS-funded trial is now underway to examine the effectiveness of carotid endarterectomy in patients without symptoms of TIA or stroke who are taking aggressive stroke prevention medications.

Stenting involves inserting a catheter with a wire inside of it into the diseased artery and then passing a tube-shaped device made of a mesh-like material over the wire. The stent is compressed until it is threaded it into position, where it is then expanded to widen the artery and flatten the obstructing atherosclerotic plaque.

**In the Carotid Revascularization vs. Stenting Trial (CREST)—a trial funded by NINDS—scientists compared endarterectomy with stenting. The findings showed that the overall safety and effectiveness of the two procedures was largely the same, with equal benefits for both men and women and for people who had previously had a stroke and for those who had not. However, the study showed that older people generally had a better outcome with surgery and younger people fared better with stenting.**



The carotid arteries are the main suppliers of blood to the brain.

**In another NINDS study involving stenting, scientists compared the effectiveness of medical treatment plus stenting to medical treatment alone for the prevention of recurrent stroke in people who have severe stenosis of an intracranial artery. Results showed that aggressive medical treatment alone is better for preventing a second or recurrent stroke, and that stenting the intracranial artery increased a person's post-operative risk of developing a stroke or major bleeding from complications of the procedure.**

### **Clot removal**

**Although the use of t-PA is the only medically proven treatment to dissolve a clot in patients with large arteries blocked by large clots, the drug does not open the vessel in time. To obtain reperfusion**

(normal blood flow) in such patients, specially trained neurointerventionalists thread a catheter (a thin, flexible tube) through the artery to the site of the blockage and use a variety of devices to open the artery. These include applying suction to vacuum out the clot. A corkscrew-like device can be extended from the tip of a catheter and used to grab the clot and pull it out. Several large, recent clinical studies have shown the benefit of stent-like devices to retrieve clot and return blood flow in people with large vessel occlusions (large clots in blood vessels) resulting in severe strokes. Severe strokes are those that can cause lifelong loss of independent functions and are often caused by blood clots that suddenly enter and block one of the main arteries that supply blood flow to the brain. A recent NINDS-funded trial showed that perfusion brain imaging using MRI or CT can identify some patients with large artery occlusion who benefit from clot retrieval up to 24 hours after stroke.

33

Recent advances in endovascular thrombectomy offer new opportunities to consider neuroprotective agents to extend the time window to restore blood flow to the brain, protect surrounding tissue, and improve long-term functional outcome. Studies planned through the NIH Stroke Preclinical Assessment Network will determine if an add-on intervention can improve outcome compared to restoring blood flow alone and lead to clinical trials using the most promising neuroprotective therapies.

## **Hemorrhagic stroke treatments**

Treatment for hemorrhagic stroke involves finding the source of the blood leak and controlling it. Hemorrhagic strokes get worse with thrombolytic medications, making it important to determine the major stroke type before starting emergency treatment.

## **Aneurysmal Subarachnoid Hemorrhage**

Bleeding from a ruptured cerebral aneurysm, called subarachnoid hemorrhage, causes a very severe headache that comes with a split-second onset. It may cause immediate loss of consciousness, but some people only experience the thunderclap headache. Survivors are at high risk for re-rupture of an aneurysm, so they desperately need emergency care. It is critically important to treat an aneurysm that has ruptured as recurrent bleeding is almost always fatal.

One surgical procedure for treatment of brain aneurysms is a technique called “clipping.” Clipping involves an operation during which an experienced neurosurgeon places a clamp on the aneurysm neck to prevent the chance that it will burst, often providing a cure.

The endovascular coil technique (also called endovascular embolization) also treats high-risk cerebral aneurysms. A small detachable platinum coil is inserted through an artery in the thigh and threaded through the vessel to the site of the aneurysm. The coil is then released into the aneurysm, where it triggers clotting and an immune response from the body. This immune response strengthens the artery walls and reduces the risk of rupture.

In cases where the aneurysm is not amenable to clipping or coiling and there is a high risk of hemorrhage, it may be necessary to occlude (close or block off) the artery feeding the aneurysm.

These procedures are used to treat aneurysms that have ruptured, as well as large aneurysms (greater than 7-10 mm) in individuals with no symptoms (asymptomatic) and small aneurysms in someone with a prior aneurysmal bleed or a family history of

aneurysmal bleeding. Treatment in asymptomatic individuals with smaller aneurysms and without a history of rupture is more controversial.

Patients with a ruptured cerebral aneurysm require intensive care. They are at high risk of developing a widespread narrowing, or vasospasm, of brain blood vessels in the ensuing two weeks due to the irritating effects of the blood. Vasospasm can cause ischemic brain injury and is managed by medical and endovascular treatments. Such patients also frequently have blood clots blocking the flow of cerebrospinal fluid in the brain, causing a buildup of pressure inside the head that requires inserting a shunt catheter into the fluid-filled cavities in the brain (called the ventricles) to divert the flow of fluid. CT scanning can monitor the degree of enlargement of the ventricles, called hydrocephalus.

### **Intracerebral hemorrhage**

35

The most common hemorrhagic stroke subtype is intracerebral hemorrhage (ICH), which is caused by years of high blood pressure that weakens a small artery in deep brain regions. Multiple clinical trials of emergency surgery to remove the clot have not confirmed benefit. Intensive care medical treatment of hydrocephalus and brain edema (swelling) is critical in the acute period and during rehabilitation. In some patients the blood is primarily in the fluid-filled ventricles of the brain, but the clots frequently block the flow of cerebrospinal fluid—leading to hydrocephalus. Inserting a ventricular shunt to drain the blood and manage hydrocephalus is essential in these cases.

- Intracerebral hemorrhage also may result from an arteriovenous malformation that bleeds. Arteriovenous malformations (AVMs) are

abnormal, snarled tangles of blood vessels that cause multiple irregular connections between the arteries and veins. These malformations most often occur in the spinal cord and in any part of the brain or on its surface but can develop elsewhere in the body. Treatment for an AVM may include conventional surgery to remove the AVM; endovascular embolization using detachable coils, tiny balloons, or fast-drying glue to block blood flow into the AVM; and radiosurgery, in which a highly focused beam of radiation is aimed directly on the AVM and causes scarring of the walls of the AVM's blood vessels. Over the course of the next several months, the irradiated vessels gradually degenerate and eventually close, leading to the resolution of the AVM.

- In elderly individuals, intracerebral hemorrhage closer to the surface of the brain—called lobar hemorrhage—can occur due to infiltration of the small brain blood vessels by Beta-amyloid, the same substance that accumulates in patients with Alzheimer's disease. Amyloid angiopathy can cause recurrent bleeding but there are no specific therapies available at this time to prevent rebleeding.
- Cavernous angiomas are malformations that appear as small grape-like lakes of blood without obvious feeding blood vessels. They leak to cause small hemorrhages. Surgery is an option if these angiomas cause recurrent bleeding and their location is accessible to the neurosurgeon.
- Clots in the brain's venous drainage system also can cause intracerebral hemorrhage as well as edema. They are treated with careful anticoagulation and occasionally with devices to remove clots from the veins.



## Rehabilitation

Rehabilitation is vital to stroke recovery. Stroke is the number one cause of serious adult disability in the U.S. and worldwide, but most people with stroke have some recovery of function. Ongoing research in this area has developed several potential approaches and therapies to help rehabilitate people after stroke.

- Physical therapy is the main form of rehabilitation for most people with stroke. The aim of physical therapy is to help people relearn simple motor activities such as walking, sitting, standing, lying down, and the process of switching from one type of movement to another. To achieve this, physical therapists use training and exercises to restore movement, balance, and coordination.

In one NINDS-supported stroke rehabilitation study, researchers compared at home physical therapy to a locomotor training program using treadmill walking with body weight support followed by walking practice. The Locomotor Experience Applied Post-Stroke (LEAPS) trial found that people who had a stroke and had physical therapy at home improved their ability to walk just as well as those who were treated with the locomotor training program. Study

37



Physical therapy aims to help people relearn simple motor activities such as walking.

investigators also found that patients continued to improve up to one year after stroke, defying conventional wisdom that recovery occurs early and largely ends at six months.

- Occupational therapy helps people relearn the skills needed to perform everyday activities such as eating, drinking and swallowing, dressing, bathing, cooking, reading and writing, and toileting. This type also involves exercise and training. Occupational therapists can recommend home or workplace modifications to better help the person resume living an independent or semi-independent lifestyle.
- Speech therapy helps people with stroke relearn language and speaking skills or learn other forms of communication. Speech therapy is appropriate for people who have no problems with cognition or thinking but have problems understanding speech or written words, or problems forming speech. Speech therapy also helps people develop coping skills to deal with the frustration of not being able to communicate fully. With time and patience, speech therapy can help a stroke survivor regain some, and sometimes all, language and speaking abilities.
- Vocational therapy helps people return to the workforce. Approximately one-fourth of all strokes occur in people between the ages of 45 and 65. For most people in this age group, returning to work is a major concern. It may involve relearning the more complex skills that were performed on the job or learning new skills for a different job. Vocational therapists can help people with lasting disabilities identify job skills and strengths and look for new work opportunities if necessary.

Psychological or psychiatric help can assist many people as they recuperate from stroke. Depression, anxiety, frustration, and anger are common disabilities in people with stroke. Therapy, along with medication, can help ease some of the mental and emotional problems that result from stroke. Sometimes it is useful for family members to seek psychological help for themselves, as well.

## What research is being done?

The mission of the National Institute of Neurological Disorders and Stroke (NINDS) is to seek fundamental knowledge about the brain and nervous system and to use that knowledge to reduce the burden of neurological disease. NINDS is a component of the National Institutes of Health (NIH), the leading supporter of biomedical research in the world. NINDS is the leading supporter of stroke research in the U.S.

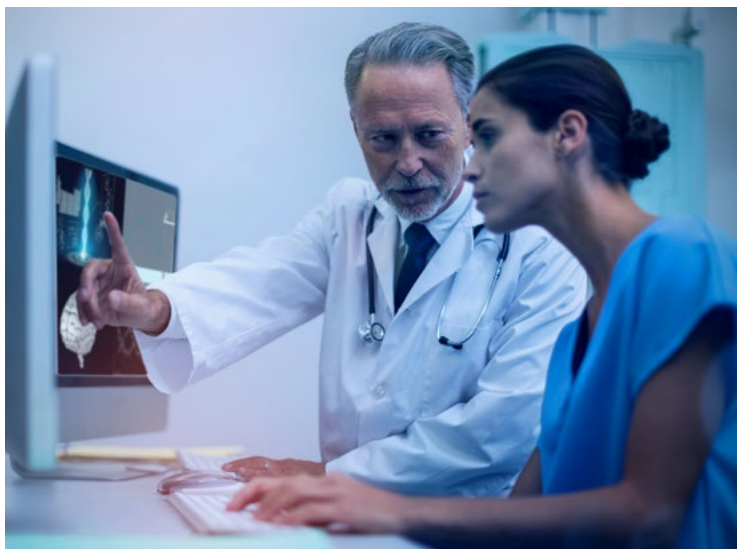
39

The Institute sponsors a wide range of basic and clinical research aimed at finding better ways to prevent, diagnose, and treat stroke, and to restore functions lost due to stroke. NINDS scientists conduct stroke research in the Institute's laboratories and clinics on the NIH campus in Bethesda, Maryland, and in two Washington, D.C. area hospitals. NINDS also funds and supports stroke research at universities, medical schools, and hospitals located around the country and the world.

Basic research helps scientists gain new knowledge and increase their understanding of stroke. This research creates the foundation for diagnosing and treating stroke. Clinical research, which makes up

a large portion of stroke research, gives scientists a way to test new treatments for people—including surgical devices, procedures, medications, and rehabilitation therapies. The overall goal of stroke research is to translate basic research findings into useful therapies and effective interventions for people with stroke.

NINDS-supported scientists are working to develop new and more effective treatments for stroke, discover ways to restore blood flow to the brain after stroke, and protect brain cells from dying after stroke. Scientists also are looking at ways to improve rehabilitation and post-stroke recovery and learn more about the risk factors for stroke in an effort to discover new methods of stroke prevention. Also, researchers are using imaging techniques to learn more about how stroke affects the brain and which stroke treatments might be effective.



NINDS sponsors basic and clinical research aimed at finding better ways to prevent, diagnose, and treat stroke, and to restore functions lost due to stroke.

## **NIH StrokeNet**

NINDS created a stroke clinical trials network that serves as the infrastructure and pipeline for exploring new potential treatments for people with stroke and those at risk for stroke. The NIH StrokeNet—which consists of a centralized coordinating and data management center and 29 regional centers that are linked to nearly 400 stroke hospitals across the U.S.—conducts small and large clinical trials and research studies to advance acute stroke treatment, prevention, and recovery and rehabilitation following a stroke.

Most recently the NINDS-funded DEFUSE 3 trial, which was conducted through StrokeNet, used advanced techniques of brain imaging to identify individuals who still might benefit from thrombectomy after its traditional 6-hour window of use from stroke onset. This trial successfully demonstrated that physically removing brain clots for up to 16 hours after symptom onset in selected individuals led to improved outcomes compared to standard medical therapy. Advanced brain imaging helped identify which patients could benefit from restoring blood flow beyond standard treatment times.

41

## **New, More Effective Treatments**

NINDS-funded research has a rich history involving medications to treat stroke, including the first approved drug to treat ischemic stroke—t-PA, or tissue plasminogen activator—and the finding that aspirin is just as effective as a medication called warfarin for preventing additional strokes. Researchers now hope to discover more effective medications, and to continue building on the clot-busting success of t-PA.

Current NINDS-funded stroke research includes:

- *Thrombolytic interventions.* These interventions are designed to prevent further brain injury caused by the stroke by dissolving blood clots that block blood flow to the brain. Several projects are testing techniques such as combining thrombolytic drugs with other drugs and delivering clot-dissolving drugs directly into the clot. Researchers also hope to find out if perfusion imaging can identify patients who can be effectively treated with t-PA when the stroke onset was not observed by anyone. Generally, a person is ineligible for standard clot busting therapy if 3 hours or 4 ½ hours have passed since the person was last seen well.
- *Antithrombotic interventions.* These drugs are designed to prevent clot formation. Among research efforts is the ARCADIA trial, which is comparing two blood-thinning drugs to determine which is better for preventing recurrent stroke in people who have stroke of unknown cause and abnormal abnormal atrial function.
- *Restoring blood flow.* The continuous blood flow to the brain is essential to brain cell health and proper function. In addition to studies using thrombolytic drugs and working to improve clot removal, other research includes using neuroimaging techniques to gain a better understanding of how blood flows to the brain—when the brain is healthy and not—to improve diagnosis, guide treatment, monitor response to therapy, identify new targets for therapy, and develop new treatments.
- *Genetics.* NINDS supports research to identify how genetics plays a role in stroke. Several rare inherited disorders cause an unusual

tendency toward stroke. One such disorder is cerebral autosomal dominant arteriopathy with sub-cortical infarcts and leukodystrophy or CADASIL—an inherited form of cerebrovascular disease that occurs when the thickening of blood vessel walls blocks blood flow to the brain. Researchers hope to identify the genes responsible for other genetic disorders, with the goals of discovering treatments and learning more about stroke.

- *Risk factors and health disparities.* With the goal of improving stroke prevention, ongoing research seeks to better understand why African Americans and Hispanics develop more strokes than Caucasians and why people in some part of the country develop more strokes than people elsewhere. For example, the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study focuses on racial and geographic differences in the prevalence of stroke risk factors by tracking health and disease in an ethnically and demographically diverse sample of the U.S. population age 45 and older. Another research effort hopes to better understand stroke disparities and develop effective interventions to reduce inadequate control of hypertension (a major stroke risk) among minority populations.
- *Recovery.* When a stroke causes cell death in an area of the brain responsible for a particular function, the person becomes unable to perform that function. However, the brain's ability to learn and change, called plasticity, and its ability to rewire the connections between its nerve cells means that it can compensate for lost function. NINDS-funded scientists are studying how the

brain responds to experience or adapts to injury to one section of the brain by having another part or parts take over and reorganize its functions—using noninvasive imaging technologies to map patterns of biological activity inside the brain. Other scientists are working to develop new and better ways to help the brain rewire and repair itself to restore basic functions following a stroke.



The REGARDS study, which focuses on racial and geographic differences in the prevalence of stroke risk factors, seeks to improve stroke prevention.

- ***Rehabilitation.*** Despite the recent advances in stroke treatment, more than half of stroke survivors (young and old) are left with residual impairments. NINDS-sponsored scientists are looking at brain reorganization after stroke and determining whether specific rehabilitative techniques, such as constraint-induced movement therapy (which involves constant restraint of the unaffected hand and arm with a mitt shaped like a boxing glove, so that the person is forced to use the affected hand and arm for daily activities) and to determine whether transcranial magnetic stimulation can stimulate brain plasticity and lead to improved motor function and decreased disability. NINDS-sponsored scientists also are testing a home-based telerehabilitation therapy system



to determine if it is as effective as in-clinic rehabilitation in helping people recover from stroke. Other scientists are experimenting with implantation of neural stem cells, to see if these cells may be able to replace the cells that died as a result of a stroke. NINDS works closely with the National Center for Medical Rehabilitation within NIH's *Eunice Kennedy Shriver* National Institute of Child Health and Human Development in supporting several efforts targeted at improving lost function and reducing disabilities following a stroke.

- *Neuroprotection.* Recent advances in endovascular thrombectomy offer new opportunities to consider neuroprotective agents to extend the time window to restore blood flow to the brain, protect surrounding tissue, and improve long-term functional out-come. The NIH Stroke Preclinical Assessment Network aims to determine if an add-on intervention can improve outcome compared to simply restoring blood flow alone.
- *Outreach programs.* NINDS's outreach programs also play an important role in linking research and practice by educating individuals, their families and friends, and healthcare providers about the latest advances in treatment and prevention. The Know Stroke campaign encourages the public to learn the signs of stroke and to seek immediate medical help at the first signs of stroke. NINDS's newest public education campaign, Mind Your Risks, informs the public about the importance of maintaining healthy blood pressure throughout life to prevent stroke, heart attack, and cognitive decline as a person grows older.



NINDS's Mind Your Risks campaign emphasizes the importance of maintaining healthy blood pressure.

**More information about stroke research sponsored by NINDS and other NIH Institutes and Centers can be found using NIH RePORTER ([projectreporter.nih.gov](http://projectreporter.nih.gov)), a searchable database of current and past research projects by NIH and other federal agencies. RePORTER also includes links to publications and resources from these projects.**

## How can I help with stroke research?

Participating in a clinical study is an excellent opportunity to help researchers find better ways to safely detect, treat, or prevent stroke and therefore offer hope to people now and in the future. NINDS conducts clinical studies on stroke at the NIH research campus in Bethesda, Maryland, and supports stroke studies at medical research centers across the country. By participating in a clinical study, healthy individuals and people living with stroke greatly benefit the lives of those affected by the disorder. Interested individuals should talk with their healthcare provider about clinical studies and help to make the difference in improving the quality of life for all persons with stroke. For information about finding and participating in a clinical study on stroke, visit Clinicaltrials.gov at <https://clinicaltrials.gov> and enter the search term “stroke.”

47

## Where can I go for more information?

For more information on neurological disorders or research programs funded by the National Institute of Neurological Disorders and Stroke, contact the Institute’s Brain Resources and Information Network (BRAIN) at:

### **BRAIN**

P.O. Box 5801

Bethesda, MD 20824

800-352-9424

<http://www.ninds.nih.gov>

Information also is available from the following organizations:

**American Stroke Association:**

**A Division of American Heart Association**

7272 Greenville Avenue

Dallas, TX 75231-4596

888-478-7653

<http://www.strokeassociation.org>

**Brain Aneurysm Foundation**

269 Hanover Street, Building 3

Hanover, MA 02339

781-826-5556; 888-272-4602

<https://bafound.org>

**Child Neurology Foundation**

201 Chicago Avenue, Suite 200

Minneapolis, MN 55415

612-928-6325

<http://www.childneurologyfoundation.org/>

**Children's Hemiplegia and Stroke Association**

4101 West Green Oaks Blvd., Suite 305

PMB 149

Arlington, TX 76016

817-492-4325

<http://www.chasa.org>

**Fibromuscular Dysplasia Society of America**

26777 Lorain Road, Suite 408

North Olmsted, OH 44070

216-834-2410; 888-709-7089

<http://www.fmdsa.org/>

**Hazel K. Goddess Fund for Stroke Research in Women**

785 Park Road, #3E

New York, NY 10021

<http://www.thegoddessfund.org>

**Heart Rhythm Society**

1325 G Street, N.W., Suite 400

Washington, DC 20005

202-464-3400

<https://www.hrsonline.org/>

**Joe Niekro Foundation**

26780 N. 77th Street

Scottsdale, AZ 85266

877-803-7650

<https://www.joeniekrofoundation.com>

**National Aphasia Association**

P.O. Box 87

Scarsdale, NY 10583

212-267-2814; 800-922-4622

<http://www.aphasia.org>

**YoungStroke, Inc.**

P.O. Box 692

1201 Creel Street

Conway, SC 29528

843-248-9019; 843-655-2835

<http://youngstroke.org>







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