# Cerebral Bypass Surgery
## advanced level

### Overview
A cerebral bypass is a surgical procedure performed to restore, or "revascularize," blood flow to the brain. A cerebral bypass is the brain's equivalent of a coronary bypass in the heart. The surgery involves connecting a blood vessel from outside the brain to a vessel inside the brain to reroute blood flow around an artery that is narrowed, blocked, or damaged. The main goal of bypass surgery is to restore blood supply to the brain and prevent strokes.

### What is cerebral artery bypass?
Blood carries nutrients and oxygen to the brain through four main arteries: the right and left carotid arteries and the right and left vertebral arteries. Poor delivery of blood flow reduces the brain's ability to function. Called cerebrovascular insufficiency, a lack of blood supply leads to transient ischemic attacks (TIA), stroke, and ultimately brain cell death. In a cerebral artery bypass, the surgeon reroutes blood flow around a blocked or damaged artery to improve or restore blood flow to an oxygen-deprived (ischemic) area of the brain. A cerebral bypass can be performed in a variety of ways depending on where the blockage has occurred, the underlying condition being treated, and the size of the brain area to be revascularized. In general, there are two types of bypasses:

The first type uses a **vessel graft** – a length of artery or vein harvested from somewhere else in the body. The graft is connected above and below the blocked artery so that blood flow is rerouted (bypassed) through the graft. Common vessels used as a graft are the saphenous vein in the leg or the radial or ulnar arteries in the arm. A separate incision is required to harvest the graft. Next, one end of the graft is connected to the external carotid artery (ECA) in the neck and then tunneled under the skin in front of the ear to the scalp. A hole is cut in the skull through which the graft is passed and connected to an artery in the brain. This method is typically used when a large (high-flow) artery is affected or needs to be sacrificed to treat a tumor or aneurysm.

The other type does not use a vessel graft but a healthy **donor artery** that flows in the scalp or face. The donor artery is detached from its normal position on one end, redirected to the inside of the skull, and connected to an artery on the surface of the brain (Fig. 1). The scalp artery now supplies blood to the brain and bypasses the blocked or damaged vessel. This method is typically used when a smaller (low-flow) artery has narrowed and is incapable of delivering enough blood to the brain.

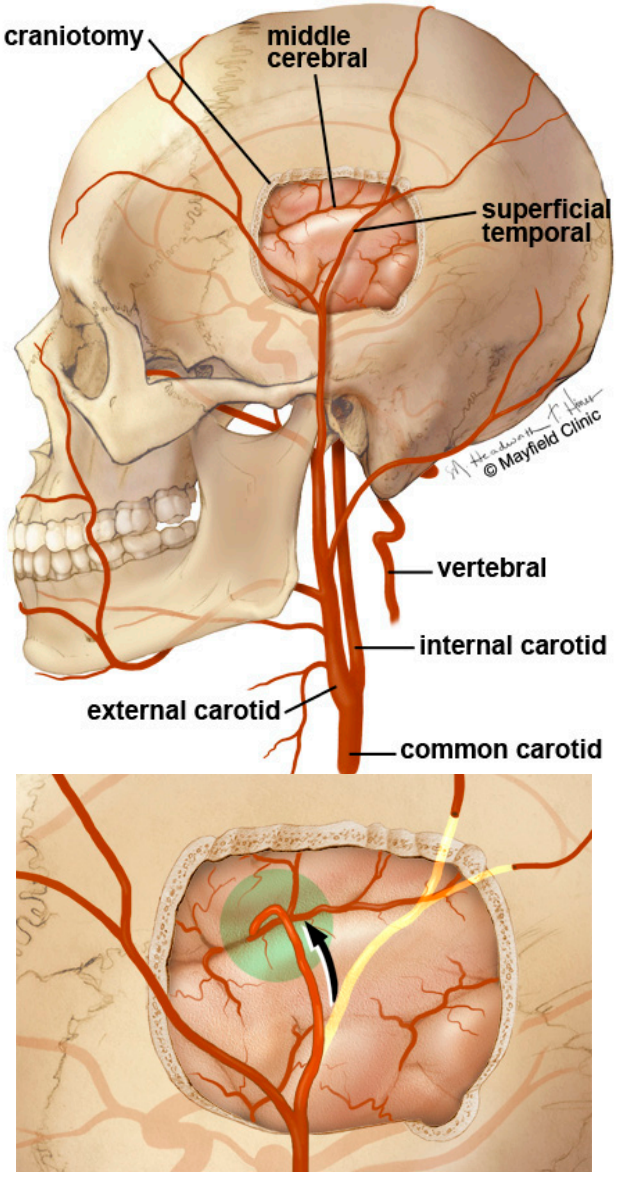


Figure 1. In a cerebral bypass surgery, an artery from outside the skull is connected to an artery inside the skull through a craniotomy. A donor artery, usually the superficial temporal artery (STA), is freed from its normal position on the scalp and connected to the middle cerebral artery (MCA) on the surface of the brain.

The most common type of bypass is the STA-MCA (superficial temporal artery to middle cerebral artery) bypass. The superficial temporal artery (STA) normally provides blood to the face and scalp. You can feel the pulse of the STA in front of your ear. The middle cerebral artery (MCA) normally provides blood to the frontal, temporal and parietal lobes of the brain. Blood flow through the MCA is often reduced when narrowing of the internal carotid artery occurs. In an STA-MCA bypass, the STA (donor vessel) is rerouted from the scalp, passed through a hole in the skull, and connected to the MCA (recipient vessel) above the blockage to restore blood flow to the brain. If the STA is too small or unsuitable, another vessel such as the occipital artery may be used.

Both types of bypasses require creating a hole in the skull to pass the vessel graft or scalp donor artery from outside the skull to the cerebral artery inside the skull. Thus, this surgery is also called an extracranial–intracranial bypass (EC-IC bypass).

## Who is a candidate?

You may be a candidate for a cerebral bypass if you have:

- an aneurysm, tumor, or atherosclerotic plaque that is not treatable by endovascular or other means
- failure of medication to control TIA symptoms or stroke
- imaging tests (angiogram, CTA, MRA) that show arterial stenosis or occlusion
- cerebral blood flow studies (CT perfusion, PET, SPECT) that show arterial stenosis is causing insufficient blood flow to the brain

Cerebral bypass may be helpful in restoring blood flow and reducing the risk of stroke in conditions such as:

- **Moyamoya disease**: a narrowing of the internal carotid arteries at the base of the brain that can cause multiple strokes or hemorrhages. To compensate for the narrowing arteries, the brain creates collateral blood vessels in an attempt to deliver oxygen-rich blood to deprived areas of the brain. A bypass can restore blood flow to the brain and prevent future strokes.
- **Aneurysm**: a bulge or ballooning of an artery wall. Some giant, fusiform, or dissecting aneurysms cannot be treated with surgical clipping or endovascular coiling. In such cases, the parent artery must be sacrificed and the blood flow bypassed for the aneurysm to be effectively treated.
- **Skull base tumor:** a tumor can grow where the major vessels enter the skull and surround or invade the artery. Removing the tumor may require sacrificing the encased artery and bypassing the blood flow.
- **Carotid artery stenosis or occlusion**: a narrowing or blockage of the carotid artery in the neck caused by atherosclerotic plaque deposits in the vessel wall.
- **Intracranial arterial stenosis**: a narrowing or blockage of an artery inside the skull that supplies blood to specific areas within the brain.

## Who performs the procedure?

A cerebral bypass is performed by a neurosurgeon. Many neurosurgeons have specialized training in cerebrovascular surgery. Ask your surgeon about his or her training, especially if your case is complex.

## What happens before surgery?

Your surgeon may order special tests to aid in planning the bypass surgery, including:

- Angiography or ultrasound evaluation of potential graft sites in the legs and arms.
- Angiography of the brain vessels to evaluate the blockage and choose the best places to connect the graft.
- Balloon test occlusion is used to evaluate whether one artery can be temporarily or permanently blocked without significantly affecting the level of blood in your brain. Performed during an angiogram, a balloon is advanced through a catheter to the artery. The balloon is temporarily inflated to stop blood flow and your condition is monitored. Every few minutes your hand grip, foot flexion and extension, language, memory, and facial expression is checked for signs of weakness. If you have good collateral blood vessels, the other arteries send enough blood to the brain so there is no change in brain function. The balloon is usually left in place for 30 minutes, then deflated and removed. If you lack collateral connections and not enough blood gets to the brain, you may develop weakness in an arm, or difficulty speaking. If this occurs, the balloon is immediately deflated and removed. Once removed, blood flow is restored and the weakness goes away, usually within seconds.

If the pre-surgical test results are positive, you will be scheduled for surgery. In the doctor's office you will sign consent forms and complete paperwork to inform the surgeon about your medical history, including allergies, medicines, anesthesia reactions, and previous surgeries. You will need to have a complete history and physical (H&P) exam preformed by your primary care physician or in the hospital's pre-admission testing office prior to surgery. Typically, a blood test, electrocardiogram (EKG), and chest X-ray need to be performed. Discuss all medications (prescription, over-the-counter, and herbal supplements) you are taking with your health care provider. Some medications need to be continued or stopped the day of surgery.

Stop taking all non-steroidal anti-inflammatory medicines (Naprosyn, Advil, Motrin, Nuprin, Aleve, etc.) 1 week before surgery. Stop smoking, chewing tobacco, and drinking alcohol 1 week before and 2 weeks after surgery because these

activities can cause bleeding problems. You may also need to have clearance from your primary care physician or cardiologist if you have a history of other medical or heart conditions. No food or drink is permitted after midnight the night before surgery.

**Morning of surgery**

- Shower using antibacterial soap. Dress in freshly washed, loose-fitting clothing.
- Wear flat-heeled shoes with closed backs.
- If you have instructions to take regular medication the morning of surgery, do so with small sips of water.
- You should take 325mg of aspirin to thin the blood.
- Remove make-up, hairpins, contacts, body piercings, nail polish, etc.
- Leave all valuables and jewelry at home (including wedding bands).
- Bring a list of medications (prescriptions, over-the-counter, and herbal supplements) with dosages and the times of day usually taken.
- Bring a list of allergies to medication or foods.

Arrive at the hospital 2 hours before your scheduled surgery time to complete the necessary paperwork and pre-procedure work-ups. An anesthesiologist will talk with you and explain the effects of anesthesia and its risks. An intravenous (IV) line and an arterial line will be placed in your arm.

## What happens during surgery?

What happens during surgery varies depending on the type of bypass procedure. Described below is the commonly performed **STA-MCA bypass**. There are 7 steps to the procedure, which generally takes 3 hours.

**Step 1. prepare the patient**
You will lie on your back on the operative table and be given anesthesia. Once asleep, your head is placed in a 3-pin, skull-fixation device, which attaches to the table and holds your head in position during the procedure. The hair near the incision area is shaved and the scalp is prepped with an antiseptic.

**Step 2. make a skin incision**
The surgeon uses Doppler ultrasound to locate and mark the course of the superficial temporal artery (STA) on the scalp with a pen. A skin incision is made along the artery.

**Step 3. prepare the donor artery**
A branch of the STA is carefully dissected from the underlying muscle. After the STA is freed, the muscle is cut and folded back to expose the bone.

**Step 4. perform a craniotomy**
Next, small burr holes are made in the skull with a drill. The burr holes allow entrance of a special saw similar to a jigsaw. The surgeon cuts an outline of a bone window. The bone flap is lifted and removed to expose the protective covering of the brain, called the dura. The dura is opened and folded back to expose the brain.

**Step 5: prepare the recipient artery**
Working under an operating microscope, the surgeon carefully locates a branch of the middle cerebral artery (MCA) suitable for bypass. The size of the recipient vessel must be a good match for the diameter of the donor vessel.

**Step 6. attach donor and recipient arteries**
Temporary clips are placed across the donor and recipient vessels to stop the blood flow. The distal STA is cut and the end prepared for anastomosis. The surgeon then makes an opening in the side of the MCA vessel and sutures the two blood vessels together.

**Step 6. verify blood flow through the bypass**
After the vessels are attached, the surgeon releases the temporary clips and verifies there are no leaks. Using a Doppler ultrasound or special fluorescent dye, good blood flow through the bypass is verified.

**Step 7. close the craniotomy**
The dura is closed with sutures. The bone flap is replaced, but a hole is enlarged to allow passage of the bypass vessel without kinking or pressure. The bone flap is secured to the skull with titanium plates and screws (Fig. 2). The muscles and skin are sutured back together. A dressing is placed over the incision.

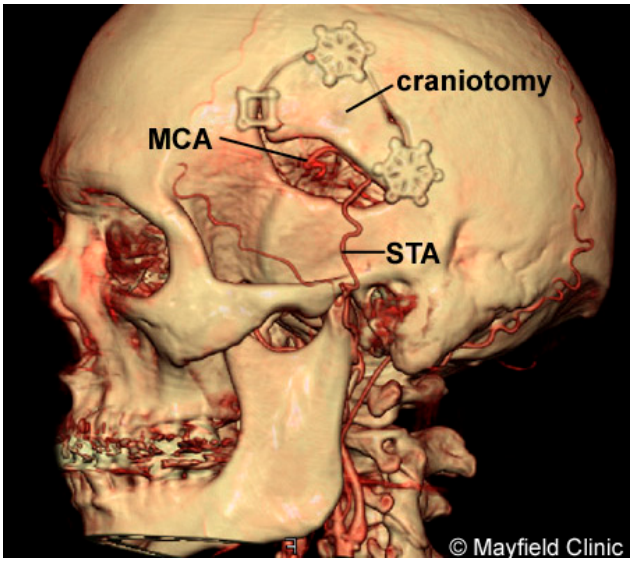


Figure 2. The superficial temporal artery (STA) is routed through a hole in the skull, called a craniotomy, and is connected to the middle cerebral artery (MCA) to restore blood flow to the brain.

## What happens after surgery?

You will wake up in the recovery area called the post-anesthesia care unit (PACU). You may have a sore throat from the tube used during surgery to assist your breathing. The breathing tube (ventilator) usually remains in place until you fully recover from the anesthesia. Once awake you will be moved to the neuroscience unit for observation. You will frequently be asked to move your arms, fingers, toes, and legs as part of the neurological exam. You may experience some nausea and headache after surgery; medication can control these symptoms. Patients are encouraged to get out of bed and walk several times a day and are encouraged to eat and drink as tolerated.

The nurse will use a device called a Doppler ultrasound every few hours to check the pulse at your incision site to ensure the new connection between your arteries is working correctly. A CT scan will be performed at some stage after surgery to confirm that no complications have occurred (especially postoperative bleeding). In 1 to 2 days you'll be released from the hospital and given discharge instructions.

## Discharge instructions

**Discomfort**

- After surgery, headache and incision pain is managed with narcotic medication. Because narcotic pain pills are addictive, they are used for a limited period of 2 to 4 weeks. Also, their regular use may also cause constipation, so drink lots of water and eat high fiber foods. Stool softeners (e.g., Colace, Docusate) and laxatives (e.g., Dulcolax, Senokot, Milk of Magnesia) can be bought without a prescription. Thereafter, pain is managed with acetaminophen (e.g., Tylenol) and nonsteroidal anti-inflammatory drugs (NSAIDs) (e.g., ibuprofen, Advil, Motrin, Nuprin; naproxen sodium, Aleve).
- An anticonvulsant medicine may be prescribed temporarily to prevent seizures. The most common anticonvulsant used after surgery is Keppra. It is usually well tolerated. Some side effects include irritability, agitation, and drowsiness.

**Restrictions**

- Do not drive after surgery until your surgeon has given you permission to do so, and avoid sitting for long periods of time.
- Do not lift anything heavier than 5 pounds (e.g., 2-liter bottle of soda), including children.
- Housework and yard work are not permitted until the first follow-up office visit. This includes gardening, mowing, vacuuming, ironing, and loading/unloading the dishwasher, washer, or dryer.
- Do not drink alcohol or operate a vehicle while using pain medication.

**Activity**

- You may feel that you do not have your normal energy level for 1 to 2 weeks after surgery. Gradually return to your normal activities. Fatigue is common.
- Walking is encouraged; start with short walks and gradually increase the distance. Wait to participate in other forms of exercise until you have discussed them with your surgeon.
- Generally you can return to work 2 to 4 weeks after surgery and can return to driving when you are not requiring pain medication during the day.

**Bathing/Incision Care**

- You may shower and get your staples or sutures wet. Use mild baby shampoo with no harsh fragrances. Be careful not to let the water directly hit your incision. Gently clean any old dried blood from the incision area.
- Do not submerge your head in a bath.
- Inspect your incision daily and check for signs of infection such as swelling, redness, yellow or green discharge, warm to the touch. Minimal swelling around your incision is expected.

**When to Call Your Doctor**

If you experience any of the following:

- A temperature that exceeds 101.5º F
- An incision that shows signs of infection, such as redness, swelling, pain, or drainage.
- Drowsiness, balance problems, or rashes while taking an anticonvulsant.
- Decreased alertness, increased drowsiness, weakness of arms or legs, increased headaches, vomiting, or severe neck pain that prevents lowering your chin toward the chest.

## Recovery and prevention

Before you leave the hospital, an appointment with a nurse practitioner will be scheduled 10 to 14 days after surgery to remove your sutures and check your recovery. If you live far away, an arrangement can be made with your primary care physician to have your sutures removed there.

An appointment for a follow-up visit with your neurosurgeon will be scheduled for 2 to 4 weeks after surgery. Follow-up imaging studies are usually scheduled 3 to 6 months after surgery to check that blood flow through the arteries and bypass graft is adequate.

Care must be taken when wearing eyeglasses. There is a risk of damaging the graft if the glasses fit too tightly over your ears in the temple area. You should use gauze to pad the area between your incision and your glasses.

Patients who undergo bypass surgery will take an anti-platelet medication (e.g., aspirin) daily. Anti-platelets thin the blood, allowing blood to flow more easily and preventing clots from forming in the bypass graft. Patients who have stomach problems should use coated aspirin and take it with food. Birth control pills increase the risk of having blood clot problems, and we recommend that bypass patients not use them.

## What are the risks?

No surgery is without risks. General complications of any surgery include bleeding, infection, blood clots, and reactions to anesthesia. Specific complications related to cerebral bypass may include:

- **Stroke** can occur from manipulation and temporary clipping of the arteries in the brain. It can also occur from graft failure, or failure of blood to flow adequately though the newly connected arteries.
- **Seizures** are a risk with any brain procedure. You will be given several days of anti-seizure medication after your procedure as a precaution. Seizures can also be caused by a potential but rare complication called a hyper-perfusion injury. Swelling and/or bleeding in the brain can occur in response to an increase in blood flow to brain areas that were formerly receiving very low amounts. Symptoms of hyper-perfusion injury include headache, facial/eye pain, or other neurological deficits.
- **Graft occlusion** occurs when blood clots form inside the donor vessel blocking off the blood flow. This is rare because blood flow measurements at the time of surgery ensure graft patency.

## What are the results?

The goal of cerebral bypass surgery is to restore blood flow to the brain and reduce the risk of stroke. The effectiveness of bypass depends on the type of graft used and the underlying condition being treated.

For moyamoya disease, studies have shown a clear benefit from bypass to increase blood flow to low perfused areas in the brain thus decreasing the risk of ischemic stroke [1,2]. The effectiveness of bypass to prevent hemorrhagic stroke is a current topic of research. Some suggest there may be a decreased risk of hemorrhage since the small fragile moyamoya vessels are no longer needed to perfuse the brain. However, reduction in moyamoya vessels is observed in only 25–65% of patients [3].

For aneurysm and tumors, results of bypass vary widely depending on the lesion location and type of bypass graft. Ask your surgeon what results you can expect.

For carotid artery occlusion, the effectiveness of bypass to decrease the risk of ischemic stroke is controversial. The role of bypass surgery for atherosclerotic carotid artery stenosis was questioned in 1985 by researchers in a clinical trial that failed to confirm a benefit of bypass against best medical treatment [4]. In the 20 years since, there has been considerable progress in imaging techniques that now enable doctors to identify a subset of stroke patients with hemodynamic ischemia, poor collateral circulation, and a high risk for recurrent stroke. The Carotid Occlusion Surgery Study is a new trial designed to determine whether STA–MCA bypass can reduce the incidence of stroke in these patients.

Although bypass surgery improves blood supply to the brain, it doesn't cure underlying carotid artery or cerebrovascular disease. Your results and long-term outcome will depend in part on taking medications as directed and following a healthy lifestyle: stop smoking, eat right, reduce cholesterol, maintain a healthy weight, control blood pressure, manage diabetes, and exercise.

## Sources & links

If you have more questions, please contact the Mayfield Clinic at 800-325-7787 or 513-221-1100. For information about the University of Cincinnati Neuroscience Institute's Neurovascular Program, call 866-941-8264.

**Sources**


1. Burke GM, et al. Moyamoya disease: a summary. Neurosurg Focus 26(4):E11, 2009
2. Baaj AA, Agazzi S, Sayed ZA, Toledo M, Spetzler RF, van Loveren H. Surgical management of moyamoya disease: a review. Neurosurg Focus 26(4):E7, 2009
3. Guzman R, et al. Clinical outcome after 450 revascularization procedures for moyamoya disease. J Neurosurg May 22, 2009
4. EC/IC Bypass Study Group: Failure of extracranial-intracranial arterial bypass to reduce the risk of ischemic stroke. Results of an international randomized trial. N Engl J Med 313:1191–1200, 1985


**Links**

www.UCCerebrovascularCenter.com
www.moyamoya.com

## Glossary

**anastomosis**: the connection of normally separate parts or spaces so they intercommunicate, as between two blood vessels.
**balloon test occlusion:** a test performed during an angiogram in which a balloon is temporarily inflated inside an artery to block the flow of blood. Used to evaluate collateral blood flow to the brain and assess whether a bypass or vessel sacrifice can be safely tolerated.
**cerebrovascular insufficiency:** an insufficient blood flow to the brain. The most common cause of decreased blood flow is atherosclerosis of the arteries that supply blood to the brain.
**collateral vessels**: a branch of an artery or vein used as an accessory to the blood vessel from which it arises; often develop to shunt blood around a blockage.
**Doppler ultrasound**: a noninvasive test that uses reflected sound waves to evaluate blood as it flows through a blood vessel.
**EC-IC bypass:** acronym stands for extracranial – intracranial bypass procedure in which an artery from outside the skull is attached to an artery inside the skull through a craniotomy.
**ischemic stroke:** stroke caused by an interruption or blockage of oxygen-rich blood flow to an area of the brain; caused by a blood clot, atherosclerosis, vasospasm or reduced blood pressure.
**hemorrhagic stroke**: stroke caused by the rupture of a blood vessel in the brain.
**occlusion**: an obstruction or closure of a passageway or vessel.
**perfuse:** to force blood or other fluid to flow from the artery through the vascular bed of a tissue.
**revascularization**: to restore blood supply to an organ by means of a blood vessel graft.
**transient ischemic attack (TIA):** a "mini" stroke caused when blood flow to the brain is temporarily interrupted and then restored; causes no permanent brain damage.

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