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HOW I DO IT - PEDIATRIC NEUROSURGERY

# How I do it: operative nuances of multiple burr hole surgery for moyamoya disease and syndrome

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## Abstract

**Background** Burr hole surgery for moyamoya disease and moyamoya syndrome is known to be an effective, versatile, and relatively simple revascularization technique. We will focus on the technical operative aspects of multiple burr hole surgery as we perform it in our center.

**Methods** Periosteal flaps are prepared and placed in a burr hole with beveled edge, after opening the dura and arachnoid membrane, in order to facilitate neovascularization into the ischemic cortex.

**Conclusions** Burr hole surgery is a versatile treatment modality for moyamoya and moyamoya-like disease. Success can be maximized by having a meticulous operative technique.

**Keywords** Burr holes · Extracranial-intracranial bypass · Indirect revascularization · Moyamoya disease · Moyamoya syndrome · Multiple burr hole surgery · Pediatric neurosurgery

**Abbreviations**

| | |
|---|---|
| MMD | moyamoya disease |
| MMS | moyamoya syndrome |
| ICA | internal carotid artery |
| STA | superficial temporal artery |
| MCA | medial cerebral artery |
| CSF | cerebrospinal fluid |
| CPP | cerebral perfusion pressure |

## Relevant surgical anatomy

Burr hole surgery is a surgical indirect revascularization procedure frequently used in moyamoya disease (MMD) and moyamoya syndrome (MMS). These diseases cause progressive stenosis of the supraclinoid internal carotid artery (ICA) and its branches with progressive formation of a network of arterial collaterals at the level of the basal ganglia. It leads to hypoperfusion, ischemia, and if untreated, stroke or hemorrhage [1, 5, 6]. The procedure is based on the creation of pedicled periosteal and meningeal flaps that are placed through cranial burr holes on the cortex of the ischemic brain (Fig. 1). Main vessels that supply these flaps are the superficial temporal artery (STA) and the middle meningeal artery respectively, originating from the external carotid artery which is generally not involved in MMD and MMS. Neovascularization will develop in these ischemic cortical regions from these flaps, serving as extracranial-intracranial bypasses.

## Pre-operative planning

Burr holes should be placed over ischemic cortex, placed in such a manner that they do not interfere with the supplying vasculature of one another (Fig. 2). They should be adjusted to the present anatomical situation, mainly in respect to the vascularization of the scalp. Avoidance of damage to existing dural-pial collaterals is achieved by inspection of the preoperative angiography [5]. Burr holes are located at least 3 cm from the midline placed at intervals of about 2–3 cm from one another [4] and in an alternating pattern (Fig. 2b–d) so that vascularization is not compromised (Fig. 2e).

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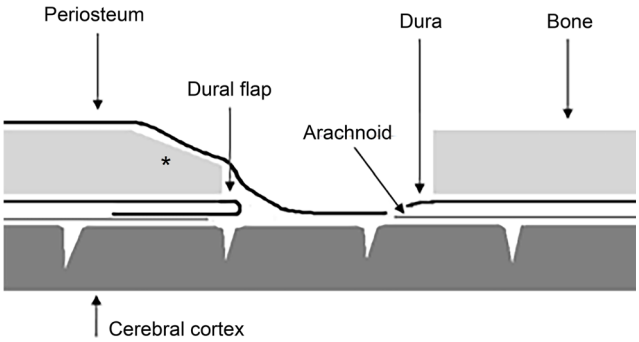


**Fig. 1** Illustration of the beveled burr hole technique. A pedicled periosteal flap is draped over the beveled edge (black asterisk) of a 14–22-mm burr hole and placed through the opened arachnoid mater on the pia mater of the ischemic or at-risk cortex. The cut edges of the meninges also give rise to neovascularization. Notice how the dura on the left is inversed. Because the outer edge of the dura (which is analogue to the periosteum) is more vascularized, it gives more rise to neovascularization

Placement up to 3 cm from the midline can result in augmented perfusion of the medial surface of both hemispheres [4, 7]. Placement up to 24 burr holes per hemisphere is possible, depending on the indication (as a standalone technique or to tailor to a specific cortical region that needs revascularization) [5, 6]. When complementary to an alternative revascularization procedure, some burr holes placed in the frontal, parietal, or occipital region can suffice.

## Description of the technique

The head is placed in a Mayfield clamp and positioned depending on the area that needs revascularization. When the use of the Mayfield is not appropriate, we place the patient on a horseshoe head rest. Duplex ultrasound or palpation can be used to localize the STA [6]. When placing multiple burr holes to cover the hemisphere, a large question mark skin flap is preferred. Other types of incision can be chosen, depending on the individual case. When exposing both hemispheres, a bicoronal incision can be chosen. An alternative approach is an incision for each burr hole separately, which can also be performed under local anesthesia.

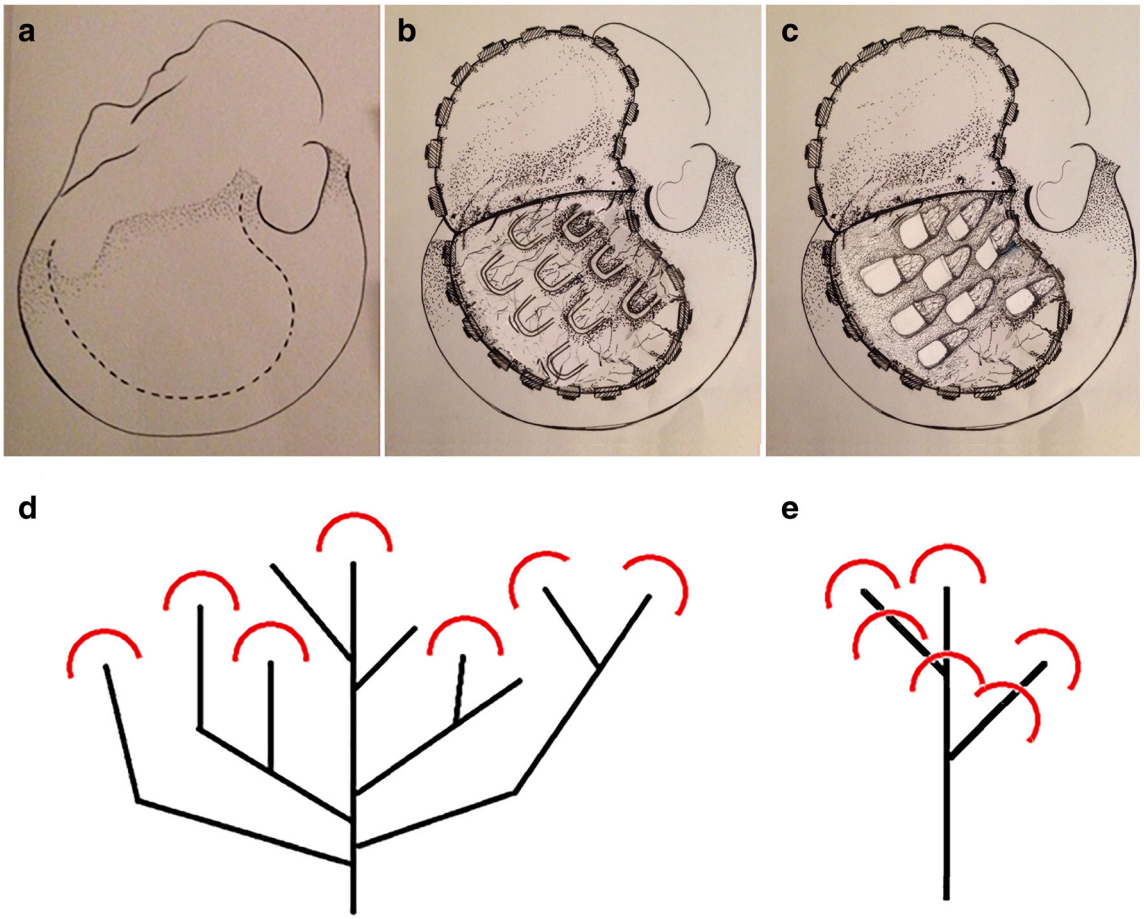


**Fig. 2** Placement of the periosteal flaps. In this example, a question mark incision is used **a**. The periosteal flaps are made in alternation with the base oriented toward the origin of vascularization **b**. Exposure of the cranial bone where the burr holes will be placed **c**. It is paramount that the flaps are placed in such a way that they do not interfere with one another and do not cut off the supply of the other flaps. This can be achieved by keeping a distance of about 2–3 cm between the flaps **d**, and trying to alternate the position in such a way that the flaps do not align **e**

The avascular plane between the galea aponeurotica and periosteum is identified and both layers are separated. The scalpel is placed on the periosteum with the sharp edge pointed toward the galea and turned at a 45-degree angle. These two layers are separated by scraping motions through this avascular plane toward the surgeon while retracting the galea. This results in an almost bloodless separation with minimal damage to the periosteum which remains adherent to the cranial bone (Fig. 2b, c). The scalp is dissected from the temporal muscle. Use of electrocautery is limited. Use of hemostatic agents (oxidized cellulose, cottenoids, collagen sponges, etc) or rinsing and compression are the preferred methods.

Arciform pedicled periosteal flaps are made over the cranium, every 2–3 cm in alternation (Fig. 2b, c). The average length of the flaps is about 2–3 cm. The flaps are regularly rinsed with saline to prevent dehydration and thrombosis of the vessels. When placing burr holes over the region of the temporal lobe, the temporalis muscle is incised and this combined muscular/periosteal flap is placed on the ischemic cortex. When the muscle is too thick, we thin out the muscle with preservation of its vascular supply.

A cranial perforator or drill bit is placed near the base of the periosteal flaps (Fig. 3d). The size of the burr holes is 14 to 20 mm. The edge at the base of the flap is beveled with a high-speed drill so a smooth transition plane is formed in order to increase contact surface with the cortex and to prevent kinking of its delicate vessels (Figs 1 and 4). A cruciate opening is made in the dura, sparing the meningeal vessels, which are also of importance for neovascularization [1, 2, 4, 7] (Fig. 5).

The arachnoid can be opened or left intact, but opening is preferential if this can be done in a safe way [1, 2, 5, 6]. The arachnoid is incised using the bevel of a needle (Fig. 5a) or with scissors. The flap is placed on the surface of the cortex (Fig. 1 and 5b). It can be sutured to the dura with a thin monofilament suture.

Fibrin glue is placed in the burr hole to prevent CSF-leakage and inflow hematoma. The galea and skin are closed using interrupted sutures. A head wrap is applied, loose enough to prevent compression of the STA.

## Indications

- Pediatric and adult cases of MMD/MMS, as a standalone technique or in combination with other (in) direct revascularization procedures (such as STA-MCA bypass surgery)
- To revascularize ischemic cortical regions that are hard to reach using other revascularization techniques.
- When direct revascularization is technically not possible (e.g., when vessels are too small for bypass-surgery)
- As a rescue strategy when after previous revascularization treatment a patient continues to have ischemic attacks [5].

## Limitations

- Revascularization takes up to 6 months do develop, during which time the patient is at risk for stroke [6]. In some cases, a direct revascularization is preferred.

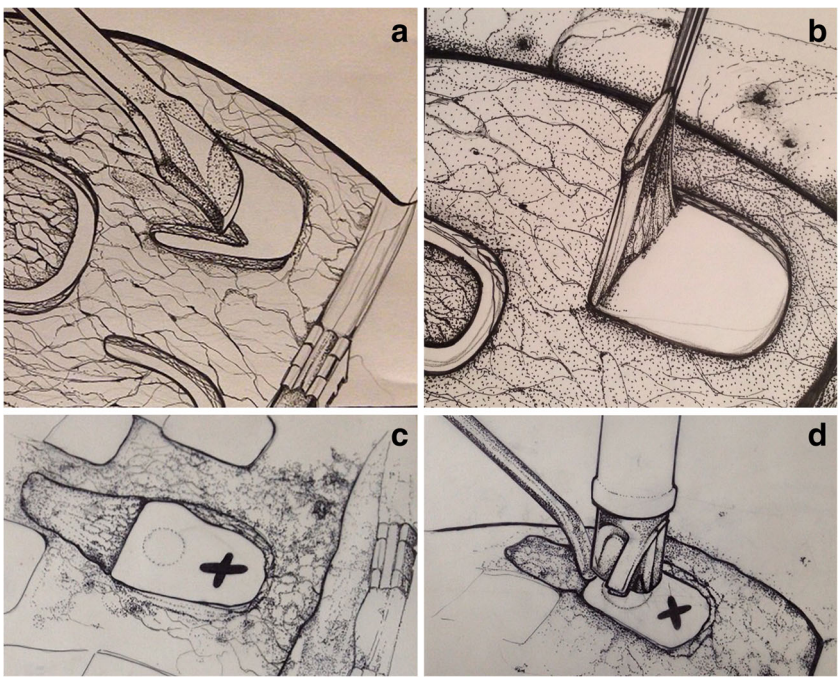


**Fig. 3** Preparation of the periosteal flaps using the dissector after incision **a**. Care must be taken not to damage too many vessels along the line of incision. Elevated periosteal flap **b**. On the exposed bone of the cranium the burr hole will be made. Placement of burr hole relative to the periosteal flap **c**. The "x" marks the length of the flap. It is important to place the burr hole close enough to the base of the flap in order to maximize the length and surface of the periosteal-cortical interface. **d.** Creating a burr hole with a disposable perforator. Here, the burr hole is placed near the base of the periosteal flap, which is protected by a Penfield dissector to prevent damage to the vessels during drilling. This technique can also be used when the burr hole is made by using a high-speed drill, for example in pediatric cases

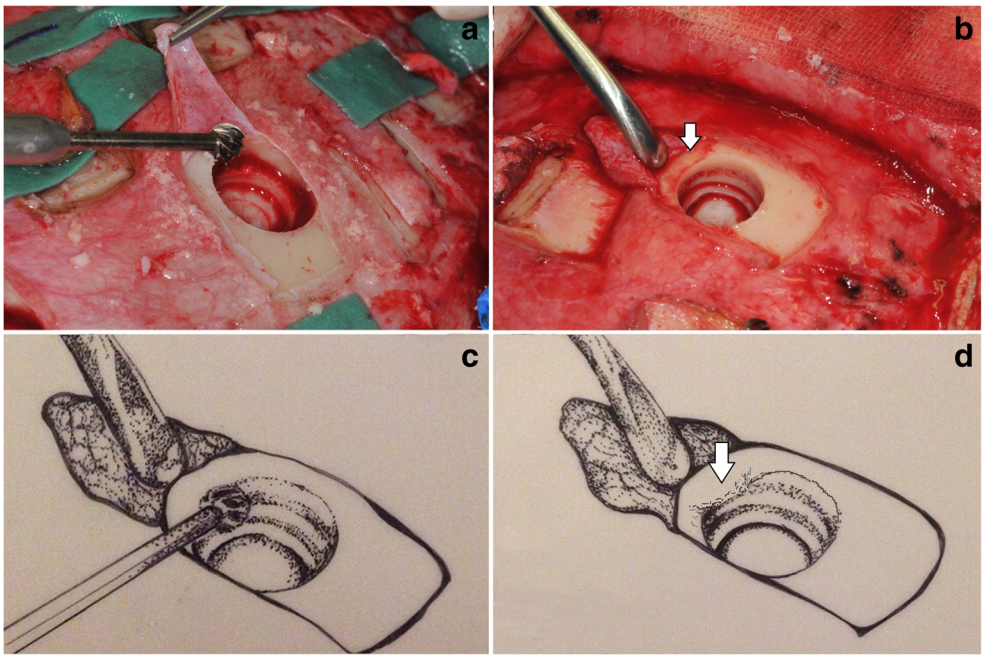


**Fig. 4** The edge of the burr hole near the base of the periosteal flap is beveled using the high-speed drill (**a** and **c**). This is done to create a smooth transition plane (**b** and **d**, white arrow) in order to increase the contact surface of the flap with the cortex and to prevent kinking (or damage) of its delicate vessels

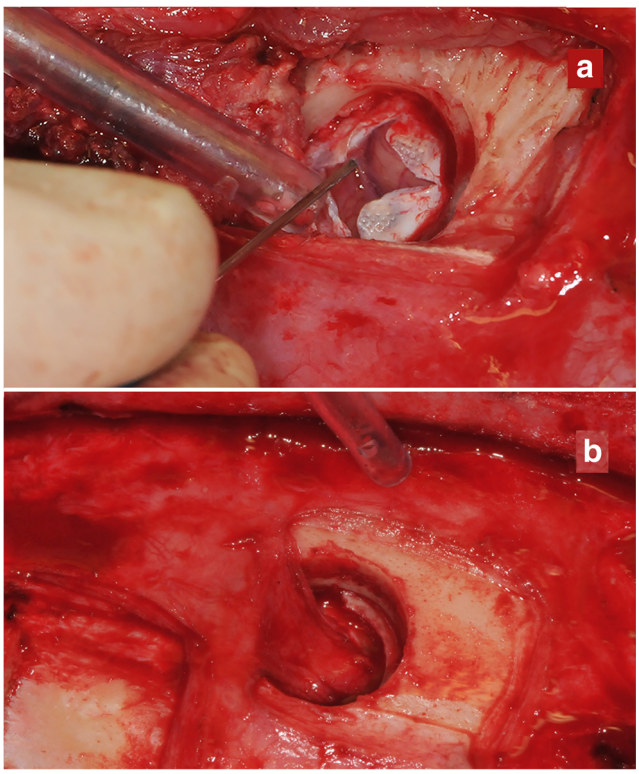


**Fig. 5** Opening the dura mater. A cruciate opening is made in the dura, preferably in a fashion that spares the meningeal vessels. Then the arachnoid mater is opened **a**. Here, a bevel of a hypodermic needle is used to precisely incise the arachnoid. After careful opening of the arachnoid, the periosteal flap is placed in the burr hole. Here, the flap is draped over the beveled burr hole edge near the base of the flap **b**

## How to avoid complications

- Preventing hypotension and to maintain CPP, normocarbia, normothermia, adequate oxygenation, and correction of anemia. Having an experienced neuroanesthesiologist is paramount in achieving these goals.
- Meticulous hemostasis and prevention of CSF-leaks

## Specific postoperative considerations

- It is important during the postoperative phase to maintain cerebral perfusion by avoiding hypotension and dehydration.
- MMS related to diseases like sickle cell anemia, specific care is of paramount importance [1, 6].
- In adults; a CT-scan of the brain is made the first postoperative day to show the location of the burr holes and to evaluate the presence of complications. In pediatrics, this is decided on an individual basis.
- Low-molecular weight heparin is given after the CT-scan.
- Subcutaneous CSF effusions are commonly observed. They be treated by compressive head dressings, needle aspiration or lumbar shunting [6].
- Early mobilization is the goal but with caution for adequate blood pressure control.

## Specific information to give the patient (or parents) about the surgery and its potential risks

- Anesthesia itself poses a risk for ischemic complications in these patients.
- Revascularization takes up to 6 months to occur, so overall stroke and hemorrhage risk is still present.
- In the immediate postoperative period (hours up to 10 days), there is an increased stroke risk, mainly being temporary and recoverable, with motor weakness and numbness as symptoms [3].
- Possible complications: Postoperative hematoma, CSF leaks, or infection.

## Relevant points

- Extensive preoperative planning is of high importance.
- Prepare the burr holes, periosteal and meningeal flaps with maximum vascularization potential.
- Meticulous eye for detail is important in maximizing outcomes.
- Working with an experienced neuroanesthesiologist is paramount in these cases.

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## Compliance with ethical standards

**Conflict of interest** First author Dr. Eno Lavrysen declares that he has no conflict of interest. Second author Prof. Dr. Tomas Menovsky declares that he has no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants performed by any of the authors.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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