Transorbital Approach for Occluding the Middle Cerebral Artery Without Craniectomy

BY MICHAEL D. O'BRIEN, M.B., M.R.C.P., AND ARTHUR G. WALTZ, M.D.

Abstract: Transorbital Approach for Occluding the Middle Cerebral Artery Without Craniectomy

An experimental model of cerebral ischemia and infarction can be produced by occluding a middle cerebral artery in animals. Most surgical approaches to the artery require removal of some portion of the cranium, which may modify or prevent the changes of intracranial pressure and the development of pressure gradients that are caused by ischemic cerebral edema or brain swelling. A transorbital approach for the exposure of a middle cerebral artery requires only enlargement of the optic foramen, which can be sealed immediately after occlusion of the artery. The lack of disturbance and manipulation of the brain and the maintenance of the integrity of the cranium result in a superior experimental model.

Additional Key Words
- cerebral infarction
- cerebral ischemia
- intracranial pressure

Occlusion of a middle cerebral artery (MCA) produces a satisfactory experimental model of cerebral ischemia and infarction in cats, dogs and primates. A retro-orbital, extradural approach to the MCA has been used by many to minimize the exposure and retraction of the brain that are inevitable with subdural approaches. However, the extradural, retro-orbital approach requires removal of a major part of the sphenoid wing of the cranium, with resulting decompression of the intracranial contents. Moreover, the surgical procedures necessary to resect the sphenoid wing can cause pathological changes in the underlying temporal lobe, and retraction of the brain through the dura occasionally may be necessary for adequate exposure of the MCA.

In 1965, Dr. T. M. Sundt, Jr., suggested a transorbital approach to the MCA to avoid cranial decompression and exposure of the dura overlying the temporal lobe. Such an approach has been described for squirrel monkeys, but the report did not give detailed descriptions of the operative procedures. The method appeared to include removal of the orbital contents, which is not suitable for cats or for long-term experiments.

Procedure

In cats, the procedure has four distinct phases: (1) internal decompression of the orbit by evacuation of the contents of the globe, (2) the approach to the optic foramen, (3) enlargement of the optic foramen, followed by mobilization and occlusion of the MCA, and (4) closure.

INTERNAL ORBITAL DECOMPRESSION

With appropriate analgesia and anesthesia, the animal's head is shaved and fixed in a head holder that does not obscure the margins of the orbit. For right-handed operators it is most convenient to place the animal with the left eye up (fig. 1). A small incision is made through the cornea and Descemet's membrane near the limbus; the cornea is removed by continuing the incision with scissors. The anterior capsule of the lens is incised and the lens is removed with lens forceps. A separate incision is made in the posterior capsule of the lens for removal of the vitreous by suction, taking care not to damage the retina. A broad-spectrum antibiotic powder, such as a mixture of polymyxin-B sulfate, bacitracin, and neomycin sulfate, can be applied topically to the interior of the globe for long-term experiments. The nictitating membrane is drawn over the exenterated globe and sutured to the conjunctiva with catgut. A partial tarsorrhaphy is made with a single mattress suture at the lateral end of the palpebral fissure.

APPROACH TO THE OPTIC FORAMEN

An incision is made in the skin and subcutaneous tissue from the lateral canthus to a point just below the infraorbital foramen, which can be palpated through the skin (fig. 1). A cutting electrical current can be used to make the incision, but if coagulation is used for hemostasis at any point in the procedure it should be bipolar. The periosteum is elevated on both the orbital

From the Department of Neurology and the Cerebrovascular Clinical Research Center, University of Minnesota, Minneapolis, Minnesota 55455.

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Figure 1
Appearance of a cat after occlusion of the left MCA via the transorbital approach. The photograph is oriented to show the proper position of the animal's head for surgery. The incision for the approach to the optic foramen can be seen.

and the external surfaces of the inferior margin of the orbit. Part of the orbital rim is removed with rongeurs; the width of bone that is removed increases from about 1 mm laterally to about 8 mm medially to unroof the infraorbital foramen (fig. 2). Removal of the inferior orbital rim is necessary to obtain the correct line of sight through the enlarged optic foramen later in the operation.

Figure 2
Left. Skull of a cat, showing a normal right orbit. O.F. = optic foramen. Right. Skull of the same cat, showing the left orbit after removal of bone from the inferior margin and enlargement of the optic foramen for exposure of the MCA. Note the orbital fissure below and lateral to the optic foramen.
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For the remainder of the approach to the optic foramen, an operation microscope is necessary. An objective lens with a focal length of 250 mm provides adequate room for instruments. At the lateral margin of the resected orbital rim the periosteum is elevated from the orbital surface of the bone to a depth of approximately 5 mm, where the orbital border of the temporalis muscle is encountered. In cats the orbit is deficient in bone inferiorly and laterally; thus, identification of the plane of dissection along the temporalis muscle is crucial to a proper approach to the optic foramen. The orbital surface of the muscle is followed laterally until the bony wall of the orbit again is encountered. Dissection continues down the lateral wall of the orbit along the line of the temporalis muscle to the optic nerve as it enters the optic foramen. The neurovascular bundle in the dura overlying the optic nerve as it enters the optic foramen is obliterated by bipolar coagulation, which also causes the nerve to shrink away from the bony margin of the foramen. The foramen then is enlarged on its superior aspect with a high-speed pneumatic drill to approximately twice its normal size (figs. 2 and 4). With care, the bone can be removed without penetration of the underlying dura which overlies the MCA. After obliteration of additional small dural blood vessels with the bipolar coagulator, an incision is made just superior to the optic nerve. The MCA then can be seen lying on the surface of the brain, sheathed in arachnoid (figs. 3 and 4). The internal carotid artery also can be seen deep to the MCA.

Without disturbing or manipulating the underlying brain tissue, the arachnoid is gently dissected from the MCA with a number 11 knife blade. The mobilized MCA can be held away from the brain for occlusion by bipolar coagulation or the application of a miniature arterial clip. The segment of the MCA that is exposed and occluded is approximately 2 mm from the bifurcation of the internal carotid artery, proximal to the point where the MCA gives rise to major branches and enters the Sylvian fissure (fig. 5).

CLOSURE

The enlarged optic foramen is less than 4 mm in diameter and can be sealed easily with dental acrylic or epoxy cement to preserve the integrity of the cranium. If desired, the bony defect can be left open, or filled with a plug of oxidized cellulose, which organizes into a satisfactory seal in a few days. A broad-spectrum antibiotic powder can be applied topically for long-term experiments. The wound is closed in layers.
Above, Appearance of the left optic foramen after enlargement but before incision of the dura to expose the MCA. The position of the cat is as in figure 1; the operation microscope is oriented so that the line of sight is perpendicular to the plane of the optic foramen. Below, left. Exposure of the left MCA (and internal carotid artery) through the enlarged optic foramen and dural incision. Below, right. Drawing corresponding to the photograph on left. L. MCA = left middle cerebral artery; L. ICA = left internal carotid artery; and L. ON = left optic nerve.

Results
The transorbital approach to the MCA has been used to produce experimental cerebral ischemia and infarction in more than 50 cats for studies of intracranial pressure and ischemic cerebral edema. Each animal has developed a moderately severe neurological deficit and a cerebral infarct. There has been no evidence of leakage of cerebrospinal fluid or infection resulting from the operative procedure. In contrast to MCA occlusion via other approaches, the neurological deficits have been remarkably similar from animal to animal, although the sizes of the cerebral infarcts have varied. The deficits have been more severe and the infarcts larger when a craniectomy is made to approach the MCA, presumably because of increases of intracranial pressure and the development of intracranial pressure gradients. Approximately one of ten animals dies of the infarct within 48 hours of occlusion.

Discussion
For acute experiments in species with a nearly complete bony orbit, including most primates, removal of the orbital contents by subperiosteal dissection provides the best exposure of the optic foramen. Orbital exenteration is not suitable for long-term experiments because of the increased risk of infection; however, the optic foramen can be exposed subperiosteally after removal of the globe to decompress the orbit. In species with an incomplete bony orbit, such as the cat, exenteration is difficult technically and provides no advantage even in acute experiments.

Removal of the globe is difficult in cats because of the shape of the orbit and the many ocular...
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FIGURE 5

Above. Base of the brain of a cat after occlusion of the left MCA (L. MCA) via the transorbital approach. The size of the defect in the dura that is required to expose the MCA can be seen, to the right and above the left optic nerve (L. ON), in the region of the label "L. MCA." L. ACA = left anterior cerebral artery. Below. Same as above, but with the dura removed. Coag = the area of coagulation of the left MCA; there is dilatation proximal to the occlusion. L. ICA = left internal carotid artery.

muscles. Orbital decompression by evacuation of the contents of the globe is preferable because it is quick and provides adequate working space with no loss of blood.

A subperiosteal approach to the optic foramen from above the globe was attempted in cats. Such an approach is relatively simple, but it is tangential to the plane of the optic foramen rather than perpendicular. More bone must be removed from the foramen to expose the MCA, which then is seen beyond the inferior surface of the frontal lobe. Local damage to brain tissue is almost inevitable when the MCA is freed from arachnoid. To provide optimal exposure of the MCA in cats, dissection along the plane of the temporalis muscle is necessary.

The transorbital approach allows adequate mobilization of the MCA so that it can be held away from the brain and coagulated with bipolar electric current without damage to cerebral tissue. Arterial spasm associated with bipolar coagulation appears to be no greater than that occurring with manipulation alone. A miniature arterial clip can be used for MCA occlusion, but it is difficult to see that the entire width of the artery is included in the jaws.
Moreover, it is difficult to seal the enlarged optic foramen with the base of the clip protruding.

When the MCA is exposed transorbitally, the surface of the brain and the dura overlying it are not exposed, disturbed or manipulated except at the point at which the MCA is mobilized. In addition, changes of intracranial pressure can develop after occlusion. Thus, the transorbital approach to the MCA provides a model of experimental cerebral ischemia and infarction that is superior to those provided by other approaches.

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