The Postorbital Approach to the Middle Cerebral Artery in Cats

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The study of the relation between behavior, cerebral blood flow, and metabolism in animal models of cerebral ischemia has gained interest in the last 10 years. The most suitable models are those with the fewest side effects. One-sided blindness caused by decompression of the eye and coagulation of the optic nerve has been an inevitable side effect of transorbital occlusion of the middle cerebral artery. The postorbital technique is a new surgical approach to the middle cerebral artery that leaves the intraorbital structures intact. After resection of the postorbital processes and gentle retraction of the eye, the optic foramen is approached with the help of an operating microscope. This approach is possible because cats have no lateral bony orbital wall. A subperiostial approach to the optic foramen is made, after which the optic foramen is enlarged. Opening of the dura gives access to the middle cerebral artery in the same way as the transorbital approach. In this way, occlusion of the middle cerebral artery is possible with minimal impairment of vision. (Stroke 1988;19:503-506)

Oclusion of the middle cerebral artery (MCA) is a widely used model of focal ischemia in humans. The transcranial intradural approach was initially used as a model for cerebral ischemia. In 1966 Sundt and Waltz published their paper on the retro-orbital extradural approach to the MCA in cats. The disadvantages of the method were the cranial resection and compression of the brain, the latter being necessary for adequate exposure of the MCA. In 1970 the transorbital approach in squirrel monkeys was described by Hudgins and Garcia and later modified for cats by O'Brien and Waltz. The clear disadvantage of this method from the metabolic point of view is the complete loss of vision in one eye due to intraocular decompression and coagulation of the optic nerve necessary to provide sufficient surgical space and adequate exposure of the MCA. In chronic behavioral, metabolic, and cerebral blood flow (CBF) studies of conscious animals in particular, an absent ipsilateral visual input impedes observation of the effect of MCA occlusion alone. For this reason, some investigators have used bilateral enucleation to avoid asymmetries. The postorbital approach to the MCA was developed by taking advantage of the lack of a bony wall on both the lateral and inferior sides of the orbit in cats.

Materials and Methods

Eight cats (3-4 kg) were anesthetized with 1.8% halothane and intubated. The area between the ear and the lateral orbital rim was shaved. Before surgery, one drop of diethoxyfosfynithiocholinate (DFTC) was placed on the cornea of the appropriate eye to lower the intraocular pressure. Since the effect of atropine antagonizes the effect of DFTC, no atropine was given preoperatively. The cat was fixed in a stereotactic frame, with the head in slight retro- and (contra-) lateroflexion. The operative side was prepared with povidone-iodine.

The orientation of the bony landmarks in the line of vision is shown in Figure 1A. The incision is made over the postorbital processes, 5 mm posterior to the lateral canthus (Figure 1B). The orbital branch of the facial nerve is identified and mobilized. The orbicularis oculi muscle (Figure 1C) is separated from the fascia and retracted medially. The inferior and superior postorbital processes (Figure 1C), in addition to the superior half of the zygomatic arch, are resected with rongeurs. Part of the superficial temporalis muscle (Figure 1D) is resected. The anterior part of the deep part of the temporal muscle (Figure 1D) is mobilized from the temporal bone and resected close to the coronoid process of the mandible. It is often necessary to ligate muscular branches of the temporal artery. The lateral aspect of the orbital contents is now clearly visible: the eye itself within the orbital fascia, the lacrimal gland on the laterosuperior aspect, and the periorbital fat around the orbital fascia (Figure 1E). Care must be taken at this stage not to open the orbital fascia in resecting the periorbital fat. Gentle retraction of the eye is necessary to proceed. Local compression of the optic nerve in particular by the retractors should, however, be avoided. A considerable amount of space is gained because of the lowered intraocular pressure. After mobilization of a small medial part of the pterygoid muscle from the sphenoid wing, the orbital fissure and the optic foramen are approached subperiostally. The orbital fissure is visible lateral to the optic foramen (Figure 1F), and the periost is then mobilized around the superior part of the optic foramen.

To achieve a proper line of vision to the MCA, a burr hole is made with a high-speed air drill on the laterosuperior side of the optic foramen (Figure 1G). The burr hole is enlarged with rongeurs until it is continuous with the optic foramen. Special care must be taken at this stage with the extraction of the bony rim.
that runs parallel to the optic nerve intracranially. To
avoid bleeding from the small meningeal branches
close to the optic nerve, the incision of the dura is
performed in the laterosuperior section of the burr hole
(Figure 1H). Bipolar coagulation should be avoided,
but Surgicel can be used if bleeding persists. To iden-
tify the carotid artery, the MCA, and the anterior
cerebral artery in the basal cistern, the cat is hyper-
ventilated once the dura is opened. The loop of the
intracranial part of the carotid artery and the MCA
with its perforating branches can be easily observed
(Figure 1I).

In acute experiments under general anesthesia, the
MCA can be occluded directly after dissection of the
arachnoid using ligation, coagulation, or small clips.
For chronic experiments, the model is prepared under
complete anesthesia; 5-0 silk suture is placed around
the MCA (Figure 1F), and with the help of a small
silicone tube, the suture is led to the vertex by subcu-
taneous tunneling. The silicone tube is then attached
to the superior postorbital process with surgical steel
and a small amount of dental acrylic. At occlusion,
about 10 days after surgery, the silicone tube is brought
to the surface after a small cutaneous incision is made
under local anesthesia. The MCA is occluded by gentle
traction on the suture, after which the suture is fixed in
such a way that reopening of the MCA is impossible.

The bone defect is filled with Surgicel, and the
orbital contents are allowed to fall back into their
normal positions. Because the perforial fat and part
of the temporal muscle have been removed, there is
now sufficient space for placement of the silicone tube.
The superficial fascia is fixed to the orbicularis oculi
muscle, thereby creating lateral tarsorrhaphia. The
wound is then closed in layers; no antibiotics are used
either preoperatively or postoperatively.

Wound infection was not observed. Postoperative
edema always resolved within 4 days, and cerebrospinal
fluid leakage has never been observed. Miosis, an
effect of DFTC, was clearly evident for at least 48
hours. Eye movements became completely normal
within a few days. The interocular alignment was
disturbed during the period of edema. When the miotic
effect of DFTC had disappeared, no anisocoria was
visible. The vision was tested with monocular light
stimuli, comparing both sides. There was a clear light
response in all chronic cats, although it was a little
slower on the operated side in four cats. There was
always a symmetric reaction after stimulation, indicat-
ing that the efferent pathway of the reflex was intact.
All cats showed Bell's phenomenon following surgery.
This never resulted in cornea lesions, probably as a
result of the tarsorrhaphia and the fact that the lacrimal
gland continued to function normally. In two cats the
blinking reflex became symmetric after 2–3 weeks.

Results

Transorbital occlusion was used in our laboratory for
many years before introduction of this new ap-
proach. Using 13 cats with transorbital occlusion as
controls, the volume of ischemia was compared. Both
groups were studied using deoxyglucose after 3 weeks' ischemia. Due to procedural differences between
the transorbital and the postorbital groups (in the trans-
orbital group, the cats were injected with 50 μCi/kg
deoxyglucose under anesthesia; in the postorbital group
the same amount was injected while the cats were
conscious), metabolic rate cannot be compared. De-
oxoglucose was injected in six of the eight cats in the
postorbital group.

The infarct area was calculated using a Hewlett-
Packard digitizing system. The area of the forebrain
hemisphere and the area devoid of metabolic activity
(including the enlargement of the ventricle) were
measured in 2.5-mm slices. The infarct volume and the
infarcted percentage of the forebrain hemisphere were
calculated and statistically analyzed using a two-tailed
Mann-Whitney U test. The results (Table 1) indicate
that there were no significant differences between the
two groups (p>0.1). There was considerable variation
in the area of the cortical infarct in both groups.

| TABLE 1. Infarct Volume and Affected Percentage of Forebrain Hemisphere 3 Weeks After Transorbital or Postorbital Occlusion of Middle Cerebral Artery in Cats |
|-----------------|--------|--------|--------|--------|
|                 | Volume (cm³) | Percentage |
|                 | Mean  | SD    | Mean  | SD    |
| Transorbital    | 13    | 2.2   | 1.5   | 18    | 9     |
| Postorbital     | 6     | 1.9   | 0.4   | 16    | 4     |

Statistical analysis using Mann-Whitney U test revealed no sig-
nificant differences between the approaches (p>0.1).

FIGURE 1. Schematic design of postorbital approach in cats. A: Bone structures in line of vision of postorbital approach; optic foramen and orbital fissure are partially masked by inferior postorbital process. B: Incision. C: Inferior and superior postorbital processes are attached by a fascia; orbicularis oculi muscle is on the right and superficial temporal muscle is on the left. D: After retraction of orbicularis oculi muscle and resection of postorbital processes, a suffi-
cient amount of temporal muscle becomes visible; eye is visible on the right, with lacrimal gland on its laterosuperior aspect. E: After excision of deep temporal muscle, temporal bone is visible partially masked by periorbital fat. F: Excision of periorbital fat and mobilization of periost with retraction of eye reveals the two adjacent transcranial pathways: laterally, the orbital fissure and medially, the optic foramen. G: A burr hole is made laterosuprora-
tic optic nerve and extended until it becomes continuous with optic canal. H: Dural incision is made on laterosuperior side of cranial opening. I: Hyperventilation reveals the carotid artery within basal cistern; loop of the carotid artery runs over intracranial part of optic nerve. J: 5-0 silk suture around middle cerebral artery and silicone tube; tube is tunneled to vertex and can easily be felt by palpation. K: Zygoma and inferior postorbital process; 2, optic foramen; 3, orbital fissure; 4, superior postorbital process; 5, temporal muscle; 6, periorbital fat; 7, eye and lacrimal gland; 8, orbital ring of orbitosphenoid bone; 9, periorbital fascia; 10, dura and epineurium of optic nerve; 11, orbital fissure and passing structures; 12, internal carotid, middle cerebral, and anterior cerebral arteries; 13, intradural part of optic nerve; 14, occluding device around middle cerebral artery. All according to Crouch. 7
transorbital postorbital

FIGURE 2. Two representative series of deoxyglucose autoradiographs in cats with 3 weeks of ischemia, clearly indicating extent of infarct. Due to procedural differences no comparisons between metabolic rates of cats is possible.

area of the subcortical infarct was less variable and corresponded well in both groups (Figure 2). The cats were used to study changes in behavior following MCA occlusion in relation to the size and extent of the infarct and metabolic rate.

The new approach was initially accompanied by loss of vision, most probably because of local compression of the optic nerve during surgical retraction. By using global retraction, by avoiding local compression at the rim of the retractor, and by careful extraction of the bony rim that runs parallel to the optic nerve intracranially, it is possible to minimize visual impairment.

Discussion

Several approaches to the MCA in cats have been described. The disadvantages of brain retraction and cranial decompression, using the subdural and extradural approaches, have all been superseded by the transorbital approach. The visual deprivation, however, is considered to be a major problem when studying the effect of MCA occlusion on CBF, metabolism, and behavior, especially because occlusion of the MCA itself induces a (partial) hemianopia by ischemia of the optic radiation.

The postorbital approach has two distinct advantages over the transorbital occlusion of the MCA. First, the undesired visual side effects following MCA occlusion are minimized. The second advantage is an ethical one: postorbital occlusion of the MCA is a less mutilating procedure, with fewer side effects for the cat. The new approach is, however, more complicated than the transorbital approach. Good equipment is essential, and more surgical training is necessary to obtain optimum results.

Since the MCA is occluded proximal to the perforating branches in both procedures, the size and extent of the ischemic area is not different when either a postorbital or a transorbital occlusion is performed. Although the burr hole may be bigger, there is hardly any cortical compression in either procedure. Even the angle between the middle cerebral fossa and the line of vision does not differ significantly (Figure 1A) when part of the zygomatic arch is resected with the inferior postorbital process. O'Brien and Waltz, approaching from the anterior (right) side, achieved a line of vision resulting in about the same angle to the skull base as that achieved in the postorbital approach.

The same procedure was attempted in Macaca fascicularis by resecting the lateral orbital wall. Because of the development of the temporal lobe in monkeys, access to the MCA was impossible. It is, however, quite possible to reach the anterior cerebral artery.

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References


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