Implanted Device for Middle Cerebral Artery Occlusion in Conscious Cats

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SUMMARY A simple implantable device was applied to the left middle cerebral artery of adult cats. One week later the artery was occluded acutely while the animals were conscious. Forced circling and tonic deviation of the head and neck toward the left were noted within seconds of occlusion. A right hemiparesis developed one to two minutes later. Cerebral angiography confirmed the presence of the middle cerebral artery occlusion when the occluding stylet was inserted. Removal of the stylet resulted in reopening of the artery. Light microscopic examination of the brains revealed severe acute ischemic changes in a large left cortical and subcortical area. Partial loss of endothelial lining and thinning of the media were demonstrated in the compressed segment of the middle cerebral artery.

HAYAKAWA AND WALTZ produced large cerebral infarcts in cats by applying traction to a ligature which had been attached previously to a middle cerebral artery. This technique allowed them to study the effects of acute focal ischemia in conscious animals with an intact cranium.

One important disadvantage of the ligature method is the inability to reopen the artery after it has been occluded. This prevents the study of transient artery occlusion and the adequate perfusion of the ischemic tissue with fixative or other agents. The object of this investigation has been to develop a simple implantable device which produces reversible occlusion of an intracranial artery in a conscious animal with an intact cranium.

Methods

Construction of Occluding Device

The components of the occluding device are shown in figure 1. Construction of the device was relatively simple and sophisticated tools not required. The slotted housing was made from a 4.5 cm, thin-walled, 16 gauge, stainless steel tube. The distal end was flattened slightly and a 1.5 mm hole drilled. A 90° rotation of the device allowed the artery to slip into the slot. A small piece of gelfoam and some thin silastic sheeting were used to close the space between the distal limbs of the hook and small files were used to smooth the rough edges. A short side-arm made from piano wire was attached approximately at the mid-shaft position and directed 180° from the opening of the distal slot. The side-arm prevented movement of the housing in the epoxy cement (see below). A piano wire handle directed 90° to the plane of the distal bevel was attached to the proximal end with solder. One end of the handle was shorter than the other thereby allowing correct alignment of the occluding stylet following insertion into the slotted housing (fig. 1B). The bevelled contour of the distal end of the occluding stylet prevented rotation within the slotted housing.

The short stylet, approximately 4 cm in length, was constructed from thin-walled, 18 gauge, stainless steel tubing. Its distal end was filled with solder. It was inserted in order to prevent leakage of cerebrospinal fluid prior to occlusion of the middle cerebral artery.

Implantation of Occluding Device

Six adult cats with a mean weight of 3,000 gm were anesthetized with sodium pentobarbital (30 mgm/kg intraperitoneally). The head was shaved and fixed in a head holder which allowed unobstructed access to the left orbit. A 2 cm curved incision was then made below and lateral to the palpebral fissure. The orbital contents were evacuated and a small 4 mm craniectomy continuous with the superolateral margin of the optic foramen was performed using a high speed drill and the operating microscope. The dura and arachnoid were opened with sharp dissection and the proximal segment of the middle cerebral artery was mobilized carefully.

The end of the occluding device (fig. 1) was inserted above the proximal segment of the middle cerebral artery with the bevel parallel to the vessel. A 90° rotation of the device allowed the artery to slip into the slot. A small piece of gelfoam and some thin silastic sheeting were used to close the craniectomy. The orbit was sprayed with neosporin aerosol and then filled with rapidly hardening epoxy cement. The short stylet was inserted to prevent leakage of cerebrospinal fluid. The incision and the palpebral fissure were closed with continuous “3-0” silk suture. The end of the implanted device protruded approximately 1 to 2 mm through the closed incision. An occlusive dressing was applied.

Prophylactic Antibiotics

Each animal received chloramphenicol (30 mgm IM) immediately before the insertion of the device and again on the following day.

Occlusion of the Middle Cerebral Artery

One week following implantation of the device, the short stylet was removed and the occluding stylet inserted.

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Cerebral Angiography

Three hours following occlusion the animals were anesthetized with pentobarbital (30 mgm/kg intraperitoneally). The left lingual artery was exposed through a small incision and a small silastic catheter inserted. Three injections of 60% hypaque (1 cc/injection) were performed: 1) with the occluding stylet inserted; 2) with the occluding stylet withdrawn 3-4 mm; and 3) with the occluding stylet reinserted.

Fixation Technique

The animals were perfused through a cannula in the ascending aorta 4 hours following the initial occlusion of the middle cerebral artery. The occluding stylet was removed immediately prior to perfusion. The animals were initially perfused with 50 ml of isotonic saline followed by a mixture of colloidal carbon (200 ml) and phosphate-buffered 4% paraformaldehyde solution (200 ml).

Tissue Preparation

The brains were removed one hour following perfusion and placed in the phosphate-buffered 4% paraformaldehyde solution. One week later the brains were cut into 5 mm coronal slices. Thin (10μ and 25μ) coronal sections were prepared from paraffin-embedded slices of both hemispheres and stained with hematoxylin and eosin. The segment of the middle cerebral artery which had been occluded was removed and embedded in paraffin. Serial sections of the vessel were cut and stained with hematoxylin and eosin.

Results

Postoperative Recovery

Insertion of the device appeared to be well tolerated and on the second postoperative day all animals were active and eating their regular diet. None of the animals developed wound infection.

Neurological Findings

Within a few seconds of the insertion of the occluding stylet, the animals began to walk in circles toward the side of the occluded vessel. The head, neck and trunk were tonically deviated in the same direction. Weakness of the right limbs was noted within one to two minutes and was more severe in the forelimbs. Forced ambulation persisted for 10 to 20 minutes following which the animals lay quietly. The severity of the hemiparesis was seen to increase slightly over the following 3 hours.

Cerebral Angiography

Cerebral angiography demonstrated occlusion of the middle cerebral artery with the occluding stylet inserted. Withdrawal of the occluding stylet was followed by prompt filling of the major left middle cerebral artery branches with the contrast media (fig. 2).

Macroscopic Examination

The left middle cerebral artery and its major branches contained carbon. In two animals there was some flattening

Figures 1 and 2. Lateral roentgenograms of cat head. A. The slot (large arrow) is obliterated by the occluding stylet. The branches of the middle cerebral artery are not visualized. B. The slot (large arrow) can be seen when the occluding stylet is withdrawn 3 to 4 mm. Major branches of the left middle cerebral artery (small arrow-heads) contain hypaque.
angiography and again at the time of perfusion. Each animal
open when the occluding stylet was removed at the time of
occluding stylet inserted. As well, the artery was shown to
scious. Cerebral angiography confirmed occlusion with the
region.

there was some loss of smooth muscle detail in
previously occluded segment of the middle cerebral artery
small lenticulostriate artery at the time of insertion of the
left basal ganglia which appeared to be subacute in
cytic processes. In one brain there also was a small infarct in
middle cerebral artery corresponding with the zone of pallor
left middle cerebral artery was poorly stained with carbon
(fig. 3). The left hemispheres appeared slightly swollen. The
tissue appeared to be well fixed.

Microscopic Examination

Light microscopic examination confirmed the presence of
severe acute ischemic changes in the distribution of the left
middle cerebral artery corresponding with the zone of pallor
observed grossly. Previous experience has suggested that
morphologic alterations of this severity are probably irre-
versible.\textsuperscript{2-4} The capillary channels were narrowed, presum-
ably the result of compression by swollen pericapillary astro-
cytic processes. In one brain there also was a small infarct in
the left basal ganglia which appeared to be subacute in
nature. It was thought to be related to the interruption of a
small lenticulostriate artery at the time of insertion of the
device. There appeared to be some loss of endothelium in the
previously occluded segment of the middle cerebral artery
but no evidence of clot formation. The media was thinned
slightly and there was some loss of smooth muscle detail in
the region.

Discussion

A device was applied to the left middle cerebral artery of 6
adult cats using a transorbital approach. One week later the
vessel was occluded acutely while the animals were con-
scious. Cerebral angiography confirmed occlusion with the
occluding stylet inserted. As well, the artery was shown to
open when the occluding stylet was removed at the time of
angiography and again at the time of perfusion. Each animal
developed a large left cortical and subcortical infarct follow-
ing 4 hours of left middle cerebral artery occlusion.

This model provides the opportunity to study acute focal
cerebral ischemia in an awake animal without the associated,
often confusing, effects of various pharmacologic agents.
Unlike most models of acute focal ischemia, the cranium is
intact and there is no leakage of cerebrospinal fluid. This is
especially important as the increase in local tissue pressure
and intracranial pressure which invariably accompany acute
cerebral ischemia\textsuperscript{1} may be significant with regard to capillary
circulation and consequent tissue viability.\textsuperscript{4} These factors
may be partly responsible for the more reliable production of
large cerebral infarcts in 10 conscious cats described by
Hayakawa and Waltz\textsuperscript{1} as compared with smaller, less
reliable infarcts which followed acute middle cerebral artery
occlusion in anesthetized cats with open craniectomies.\textsuperscript{4-8}
The results of this investigation appear to confirm the find-

The advantages of using the device described in this in-
vestigation include: 1) ease of application; 2) ability to con-
trol vessel occlusion more precisely; and, 3) potential to
remove the occluding stylet following a short period of occlu-

Potential disadvantages of the device include: 1) the in-
terruption of lenticulostriate arteries during application (this
occurred in one animal); 2) possible kinking or stenosis of
the artery during or following application; and, 3) infection.
The use of prophylactic antibiotics appears to be helpful in
minimizing the incidence of infection as none of the animals
in our series developed a wound infection.

The occluding device has now been used successfully in
more than 20 cats. It is presently being employed in an in-
vestigation of the treatment of acute focal ischemia.

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