A technique for placement of an indwelling carotid artery catheter in the rhesus monkey is presented. These indwelling catheters have proved useful in the investigation of regional cerebral blood flow using xenon-133, positive contrast angiography, and fluorescein angiography. Although limited thus far to studies in experimental anemic stroke, this technique could be adapted to a variety of experimental situations in which serial evaluations of the cerebral vasculature are indicated.

KEY WORDS  •  experimental stroke  •  cerebral blood flow  •  cerebral angiography

In the experimental investigation of questions related to the cerebral circulation, it is frequently desirable to perform serial examinations, sometimes over protracted periods of time, which require injection of materials directly into the cerebral vessels. Repeated surgical exposure of these vessels is generally limited by unacceptable scar formation and, even when feasible, is likely to result in undue trauma to the vessel involved as well as in significant variability in injection site. We have recently developed a technique for placement of an indwelling polyethylene (PE) catheter in the internal carotid artery (ICA) of the rhesus monkey to facilitate sequential, regional cerebral blood flow (rCBF) and angiographic studies in evolving experimental anemic stroke. Although limited thus far by us to evaluation of the stroke model, this technique could successfully be adapted to a variety of experimental situations in which a particular vascular channel is used over an extended interval.

Materials and Methods

Indwelling ICA catheters were placed in 35 Macaca mulatta monkeys, ranging in weight from 2.5 to 4 kg. These specially designed catheters were fashioned from 50-cm lengths of PE tubing, PE 10, with an interior diameter of 0.011 in., accommodating a No. 27 needle, or PE 50, with an interior diameter of 0.023 in., accommodating a No. 23 needle.* These were heated at one end, drawn to a gentle taper, and expanded to a small bubble just proximal to this tapered segment; the tapered tip was then trimmed to a length of 0.7 cm (Fig. 1 left). Catheters were placed overnight in tridodecylammonium chloride-heparin complex (TDMAC†), a heparinizing...
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Fig. 1. Left: Proximal end of indwelling polyethylene catheter (PE 10). The tapered tip beyond the catheter's dilated segment is placed intraluminally. Right: Operative photograph showing catheter (PE 10) in place within the right internal carotid artery (upper arrow) of a rhesus monkey. The distal portion of the catheter is sutured to the adventitia of the common carotid artery (lower arrow) with spaced sutures of 8-0 Ethilon. × 3. Measurement is in centimeters.

All animals were anesthetized for surgery with ketamine hydrochloride (Ketaset®), 10 mg/kg intramuscularly, supplemented by sodium thiamylal (Surital®), 20 mg/kg intraperitoneally. Each animal was placed on the operating table in the right lateral decubitus position with the head turned to the left and the right arm pulled down and to the right. The right neck, shoulder, chest, and abdomen were shaved and routinely prepared and draped so as to include two previously marked incisions, one along the medial aspect of the right sternocleidomastoid muscle, extending from the angle of the mandible to just above the sternal notch, and a second parallel to the fibers of the external oblique muscle, approximately 1.5 cm medial to the anterior superior iliac spine. The Zeiss operating microscope was used throughout the procedure except for opening and closure of the wounds.

The common carotid artery (CCA), its bifurcation, and the initial segments of the ICA and external carotid artery (ECA) were exposed through the cervical incision. Sutures of 4-0 Mersilene, or a comparable monofilament suture, were looped successively around the CCA, ICA, and ECA. There was less likelihood of trauma to these vessels when the suture was passed on a small, curved needle. A suture of 3-0 silk was next passed under each Mersilene loop so that simple traction on the silk suture would loosen the loop, thereby promptly relieving any vessel constriction. This was notably less hazardous than direct forceps release. After securing the ligatures loosely to the surrounding drapes, the abdominal wound was opened and connected to the cervical wound by a subcutaneous tunnel. The distal, non-tapered end of a PE catheter was drawn from the neck to the abdomen along this subcutaneous channel, filled with heparinized normal saline (5000 units/500 cc), and clamped. An area of adventitia just large enough to permit passage of the PE catheter was carefully cleared on the anterior aspect of the carotid bifurcation, and the ligatures around the CCA, ICA, and ECA were tightened, thus occluding blood flow through a Y-shaped vascular segment. The CCA was punctured with a No. 22 needle at the site of adventitial stripping, and the tapered tip of the PE catheter was passed through this punctate opening into the ICA, and advanced until the ballooned section of catheter abutted the external wall of the CCA. To effect unimpeded intraluminal advancement of the catheter, the occluding ICA ligature was made slack by traction on the silk suture passing under it, as described above. Once the catheter was within the ICA to its full extent, the ligature was again tightened. The dilated segment of catheter served not only as a convenient tampon at the point of puncture but also as a guard against progressive slippage of the catheter intra-

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‡Ketaset produced by Bristol Laboratories, P.O. Box 657, Syracuse, New York 13201.
§Surital produced by Parke, Davis and Company, Joseph Campau at the River, Detroit, Michigan 48232.
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vascularly. The catheter was anchored securely to the adventitia of the CCA with spaced sutures of 8-0 Ethilon* (Fig. 1 right), and several sutures of 6-0 silk were placed in the sternocleidomastoid muscle and tied as loose check-reins on the descending catheter. Blood flow through the carotid vessels was re-established as soon as hemostasis was attained, and this was generally achieved with the first securing 8-0 suture. After flushing with heparinized normal saline solution, the catheter was clamped, heat sealed, and tied with a 3-0 silk ligature for additional security. The unclamped catheter was then neatly coiled and placed in a subcutaneous abdominal pouch. A thin strip of Gelfoam was placed over the carotid course of the catheter, and the wounds were closed in layers. A cervical collar of rolled orthopedic stockinette was fitted to each animal to discourage extremes of neck movement, and the animal was placed in a laboratory restraining chair. While these last two measures are not always critical, they do afford added safeguards against postoperative catheter displacement or carotid artery injury.

Each time a catheter was used for study, the abdominal wound was opened, the coil of catheter removed, and the sealed end cut and fitted with an appropriate needle for injection. When the study was completed, the catheter was again flushed with heparinized normal saline, heat-sealed and ligated, and replaced subcutaneously. During periods when the catheter was used infrequently, flushing was carried out nonetheless every 2 to 3 days to insure patency.

Benzathine penicillin G suspension (Bicillin†), 300,000 units intramuscularly, was given prophylactically on the day of surgery and each week thereafter.

Results

Indwelling intracarotid catheters have proved to be useful adjuncts to at least three areas of experimental investigation: 1) rCBF using xenon-133 (Fig. 2); 2) positive contrast angiography (Fig. 3); and 3) fluorescein angiography (Fig. 4). We have found PE 10 catheters satisfactory for rCBF and fluorescein angiographic studies, although the larger PE 50 catheters have been required for positive contrast angiography. While alteration in blood flow by the intraluminal mass of the catheter is a theoretical consideration, no suggestion of obstruction either to carotid or cerebral flow could be demonstrated by aortic arch arteriography in an animal with a PE 50 catheter indwelling in one ICA (Fig. 5). Although these catheters have remained patent and functional for as long as 8½ weeks following placement, no attempt has been

*Ethilon suture manufactured by Ethicon, Incorporated, Somerville, New Jersey 08876.
†Bicillin produced by Wyeth Laboratories, Lancaster Avenue and King of Prussia Road, Radnor, Pennsylvania 19087.

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made to determine limits of their practical longevity.

In general, any laxity in attention to detail can be expected to be reflected in complications. Premature clotting of the catheter occurred in one animal when heat-sealing alone, rather than heat-sealing plus ligation, was used for catheter closure. There were three cases of postoperative occlusion of the ICA secondary to intraoperative trauma. If the precaution is taken whereby occluding ligatures are released indirectly (see Methods), such injury is less apt to occur. In two animals the catheter was dislodged from the ICA into the surrounding soft tissues as a result of inadvertent tugging on the distal limb in the course of study. There was one abdominal wound infection attributable to direct contamination; there were no cervical wound infections.

In an effort to determine whether or not long-term use of the indwelling catheter was associated with significant arterial wall injury, the CCA, its bifurcation, and the ICA from four animals, two with PE 10 and two with PE 50 catheters, were examined histologically 3½ to 4½ weeks following catheter placement. Serial sections stained with hematoxylin and eosin and Gomori's aldehyde fuchsin demonstrated injury localized to the site of catheter penetration into the ICA. In one case in which the catheter had been nonfunctional for 4 weeks, a mural thrombus had recently formed and endothelial cells had begun to invest the intraluminal portion of the catheter.

Discussion

A method for placement of an indwelling catheter in the ICA of the rhesus monkey is presented. This procedure, already well tested in investigations of rCBF and cerebral angiography, should lend itself favorably to a variety of experimental studies in which serial, standardized evaluations of the cerebral vasculature are indicated. Careful attention to details of both catheter placement and subsequent postoperative catheter management is essential to the success of this useful technique.

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