Experimental Carotid Ligation Followed by Aneurysmal Formation and Other Morphological Changes in the Circle of Willis

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The circle of Willis is of considerable importance in ensuring a continuous blood supply to the brain. In a young person with a well-developed circle of Willis, no serious effects follow the occlusion of one of the carotid or vertebral arteries, but in old people a thrombotic or embolic occlusion of a carotid artery is a very common cause of cerebrovascular incidence.\textsuperscript{4,5,11,15} The shape of the circle of Willis in the newborn is different from that in the adult. Thus the posterior communicating arteries, and also those portions of the anterior cerebral arteries belonging to the circle of Willis, are relatively narrower in the latter,\textsuperscript{4,14} and this may be a contributory factor in the development of intracerebral vascular lesions.\textsuperscript{10}

Material and Methods

Forty-two rabbits were used. Of these, 22 were 3 weeks old and came from 7 litters, while the remaining 20 were about 1 year old (weighing 2,500–3,000 gm.).

Ten young rabbits and 10 old ones were chosen at random. In these animals the carotid artery on one side of the neck was ligated. In the rabbit, the internal carotid artery is very small and branches from the common carotid artery close to the skull. For practical reasons, a ligature was applied to the common carotid before the internal carotid artery was dissected free and ligated. Thus on one side of the neck both the common carotid and the internal carotid arteries were ligated.

In 2 young rabbits, the carotid artery on both sides of the neck was ligated.

In the remaining rabbits, a dummy operation was performed as a control. This operation consisted in free preparation of one common carotid artery, which then was replaced and the incision was sewn up again.

Half of the rabbits were sacrificed 1 month after operation, and the other half 5 months after operation. A total of 2 rabbits died earlier.

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After the animals had been sacrificed, the site of operation was inspected to check whether the ligation had been successful. In one half of the cases, the brains, with all large intracranial arteries intact, were placed in Bouin’s fixative. In the other half, the alternative procedure of injecting the fixative under a slight pressure (30 mm. Hg) into the aorta was adopted, so that the cerebral arteries were fixed in a distended state to eliminate the folding and contraction post mortem. After fixation, the arteries in all cases were removed from the brains and divided into short segments, each comprising only one point of branching. Detailed sketches of the segments were made in order to facilitate the reconstruction of the serial sections. The segments were stained with cosin to assist the embedding and serial-sectioning procedures. The sections were stained with various stains for elastin in combination with van Gieson or azan.

Results

The regular location and the normal histological appearance of defects of the media and of physiological cushions of the intima in the circle of Willis of the rabbit (Fig. 1A) already have been investigated.\textsuperscript{7} The sizes of cushions and defects show certain variations between individual rabbits, and in about one third of the animals, some cushions or defects are absent. The calibres of the arteries of the circle of Willis show much smaller individual variations in rabbit than in man.

Following the carotid ligation exceptionally large defects of the media were found, especially at the anterior end of the basilar artery but also at the distal end of the junction between the internal carotid and the posterior communicating arteries on both sides. The defects in the rabbits with a carotid ligature were considerably larger than those in the rabbits not ligated.

Six of the large defects found in the ligated rabbits showed a considerable bulging of the
arterial wall and a defective internal elastic lamina, as in a saccular aneurysm (Fig. 2). All these bulging defects were located on the basilar and posterior cerebral arteries. Both rabbits that had been treated with bilateral carotid ligature showed a strongly bulging defect of the media at the anterior end of the basilar artery. Two of the aneurysmal defects had been fixed by the injecting method.

Following carotid ligation, changes in the location and in the size of the cushions of the intima also were observed. At the junction of the two anterior cerebral arteries (rabbits usually have only one anterior cerebral artery distal to the circle of Willis) cushions were found in 12 of the 20 rabbits carrying unilateral ligation, and in 11 of the 18 controls. All the cushions in the ligated animals were situated mainly in the proximal region of the anterior cerebral artery on the ligated side (Fig. 1B). The cushions in the controls were situated as in Fig. 1A, with the exception of one small one located distal to the junction. In all cases extremely voluminous cushions were found on the ligated side at the junction between the internal carotid and the posterior communicating arteries. At the corresponding junction on the opposite side, extremely small cushions were found in 8 cases, while in the remaining 12 no cushion was detected. The volumes of the cushions were determined by inspection of the serial sections, and a significant difference (p = 0.04) occurred between those on the ligated side and those on the side not ligated. The cushions at the anterior end of the basilar artery also showed marked changes after ligation of the carotid. On the ligated side, no, or only extremely small, cushions were found. The cushion on the side of the basilar artery opposite to the ligation was large in all cases. In addition, a new cushion often was found at the posterior end of the posterior communicating artery on the side not ligated. The histological character of the cushions was mixed muscular-elastic, although the proportions of smooth muscle to elastic tissue varied somewhat (Fig. 3).

In all the ligated animals, the calibre of the posterior communicating artery was greater on the side carrying the ligature. The cross-sectioned area (estimated by inspection of the histological sections) was significantly greater (p = 0.02) on the side ligated than on that not ligated. The difference was more accentuated in the rabbits sacrificed after 5 months than in those sacrificed after 1 month.

Although the common carotid artery had been ligated at the neck, several well-developed anastomoses were found between the internal and external carotid systems on the side bearing the ligated artery. The direction of blood flow in these anastomoses was not investigated. The largest anastomosing channels between the external and the internal carotid systems of the ligated side were the ophthalmic, the anterior meningeal and the middle meningeal arteries. The ophthalmic artery on the ligated side showed an increase in calibre which was almost of the same magnitude as that of the posterior cerebral artery (cf. above).

Microscopic preparations of the wall of the arteries that exhibited an increase in calibre (the posterior communicating, ophthalmic