SPECIAL ARTICLES

THE IMPORTANCE OF ARTERIAL LIGATIONS FOR THE TREATMENT OF INTRACRANIAL ANEURYSMS*

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The use of carotid artery ligation for the treatment of internal carotid aneurysms has been popularized by Dandy[1] and accepted as an effective method by most neurosurgeons.[2,3] Woodhall and his co-workers[4,5] and others[6,7] have measured the intra-arterial pressure changes and showed that following occlusion of the internal or common carotid artery, a 30-70 per cent pressure decrease occurs in the distal portion of the internal carotid. Again Woodhall, comparing the clinical results and pressure changes, has stated that a 50 per cent pressure drop is necessary for the prevention of recurrent subarachnoid hemorrhage. In the past, carotid ligations have been used for anterior communicating aneurysms and proved to have no practical value. In recent years proximal anterior cerebral occlusion has been advised by Logue[8] and Baumann.[9] This method has not been accepted by all. Also, no clinical information is available about the pressure changes in the anterior cerebral artery following proximal anterior cerebral or carotid ligation.

Treatment of posterior fossa aneurysms by means of vertebral ligation is a controversial subject. Because of the rarity of these cases large series have not been collected. Only in one case, Bakay and Sweet[6] have measured pressures, in the intracranial portion of the vertebral and in the posterior inferior cerebellar artery before and after occlusion extracranially of the vertebral. They stated that a clinically useful pressure drop is not obtained in the vertebral tree after vertebral artery occlusion, assuming that the contralateral vertebral is the same size as the occluded one, although the size of the contralateral vertebral was not known in this case. On the other hand Poppen[10] and Dimsdale[11] have reported a number of cases in which ver-

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tebral ligations were used with good clinical results. These workers did not measure pressure changes, but Poppen advised ligation of the large vertebral artery for basilar artery aneurysms.

It is a well known fact that the circle of Willis presents itself with great variation in man, and this is the main factor as to whether an adequate pressure decrease will be obtained at a given point after certain ligations. It is difficult to make pressure measurements in different portions of the circle of Willis, and because of this a complete knowledge of the dynamic characteristics of this structure is not available.

In order to obtain this information an attempt was made to construct a model of the cerebral arterial tree and to circulate blood through this system by means of a cardiac pump. Pressure and flow studies were made after certain occlusions.

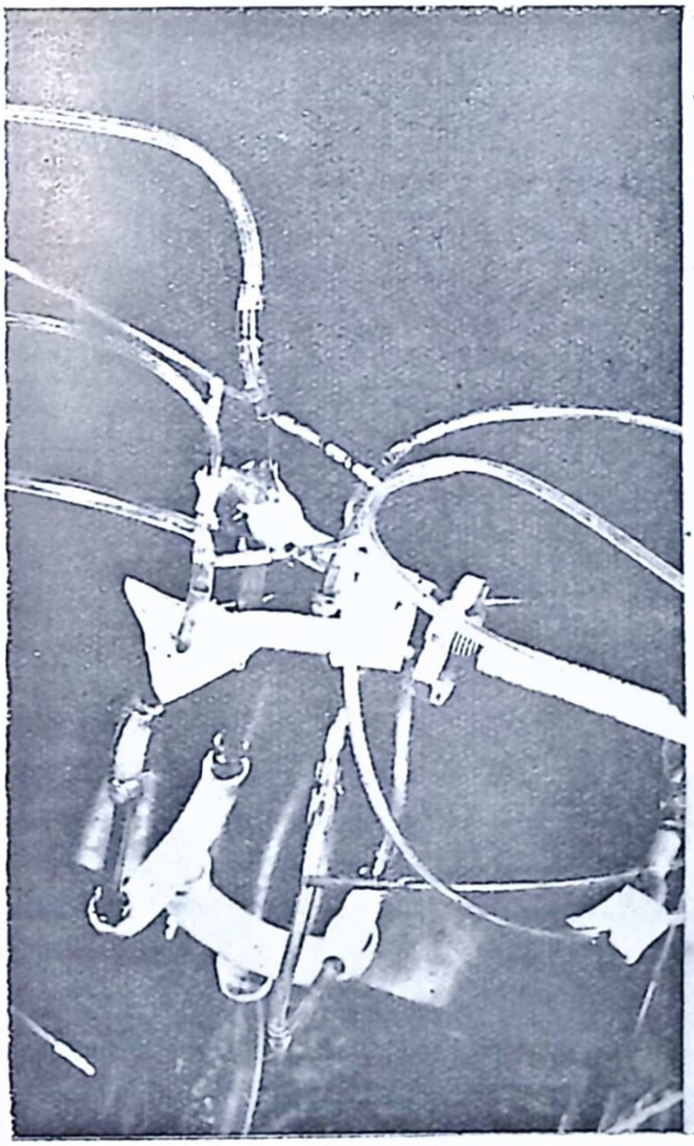
Method

Plastic tubing (polyethylene and taycon) was used. The diameters of the vessels were taken from conventional anatomy books. These diameters are: carotid 4 mm., middle cerebral 3 mm., anterior cerebral 2 mm., posterior cerebral 2.5 mm., anterior communicatings 1.5 mm., 1 mm., 0.7 mm., vertebrals 3 mm., 2 mm., 1 mm., basilar 4 mm., superior cerebellar 2 mm., posterior inferior cerebellar 2 mm., posterior communicatings 1.5 mm., 1 mm., 0.7 mm. As will be seen in figure 1, a large tube (1.5 cm. diameter) was connected with the model as a main supplying vessel. A reservoir was filled with heparinized blood and the proximal end of the main vessel was placed in it. Before reaching the model the main tube went through a Sigma Motor cardiac pump. This pump gives pulsatile flow like a normal heart. Figure 2 shows the diagram of the model. The lengths of the vessels were: internal carotid 16 cm., vertebral 10 cm., basilar 5 cm., posterior communicating 3 cm., anterior communicating 0.6 cm., proximal anterior cerebral 3.5 cm., and the distance between the posterior inferior cerebellar-vertebral and vertebral-basilar junction 4 cm. The terminal portions of the vessels were made about 70 cm. long and the terminal ends were connected with small tubes (1 cm. length and 1 mm. diameter) in order to obtain adequate resistance in the system. With 1000 ml./sec. flow a mean pressure of 100 mm. mercury was obtained. This flow corresponds to the normal cerebral flow of an adult. The pressure, which is within normal limits for an adult, was increased by 10 and 20 per cent after occlusion of the vertebral and carotid arteries respectively. Since systemic blood pressure does not change after such an occlusion in man this was simulated by decreasing pump flow. All results were recorded under 100 mm. mercury systemic pressure in the main supplying tube. As the pressures were taken distally in the system a gradual decrease was noted. At the terminal portion of the vessel only 35 mm. mercury mean pressure was observed, which corresponded to normal capillary resistance in man.

Pressure measurements were made with pressure transducers and recorded by means of a Sanborn Twin Recorder. By using a switch on the recorder, mean and pulse pressures could be recorded at the same time. As will be seen, figure 3 shows the relationship of mean and pulse pressure changes. The same amount of mean and pulse pressure decrease occurred at a given point after a given occlusion. Therefore only mean values will be given in the results.

Results

Internal Carotid Occlusions: The amount of pressure drop was the same at different points of this vessel following proximal ligations. When the diameter of the communicating arteries was 1.5 mm., the mean pressure decrease was 38 per cent. At the same time in the middle cerebral the decrease was measured as 41 per cent (fig. 4 A, B).



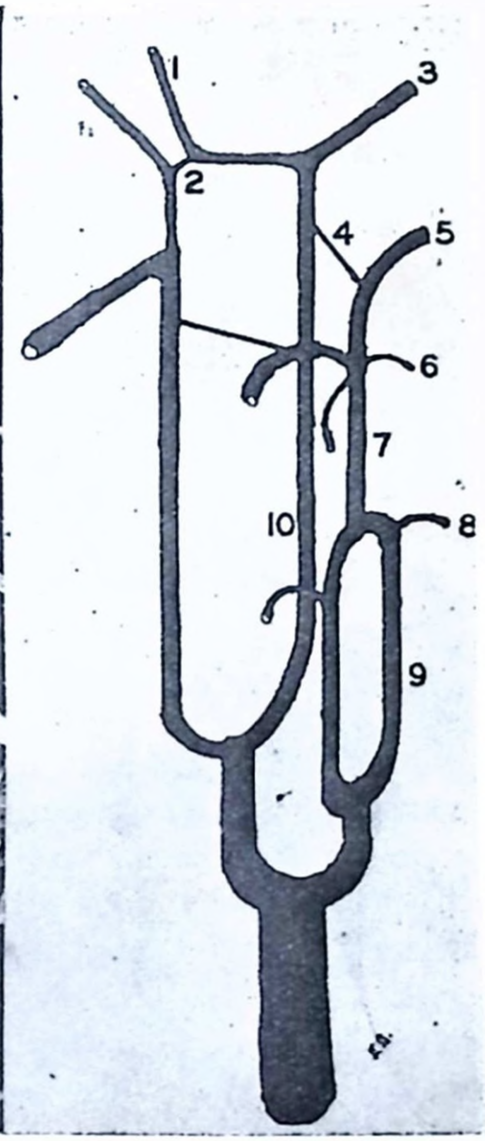


Fig. 1. — Photograph of the model. Fig. 2. — Diagram of the model.

1. Anterior cerebral. 2. Anterior communicating. 3. Middle cerebral. 4. Posterior communicating. 5. Posterior cerebral. 6. Superior cerebellar. 7. Basilar. 8. Posterior cerebellar. 9. Vertebral. 10. Carotid.

In the anterior cerebral artery the pressure drop was less than the one occurring in the internal carotid and middle cerebral (fig. 5).

Since the posterior cerebral is supplied mainly by the vertebral system, carotid occlusion has shown very little effect on this vessel. Only 10 per cent drop was recorded (fig. 6 A).

As the diameter of the communicating arteries was made smaller the percentage decreases of mean pressures increased. With the

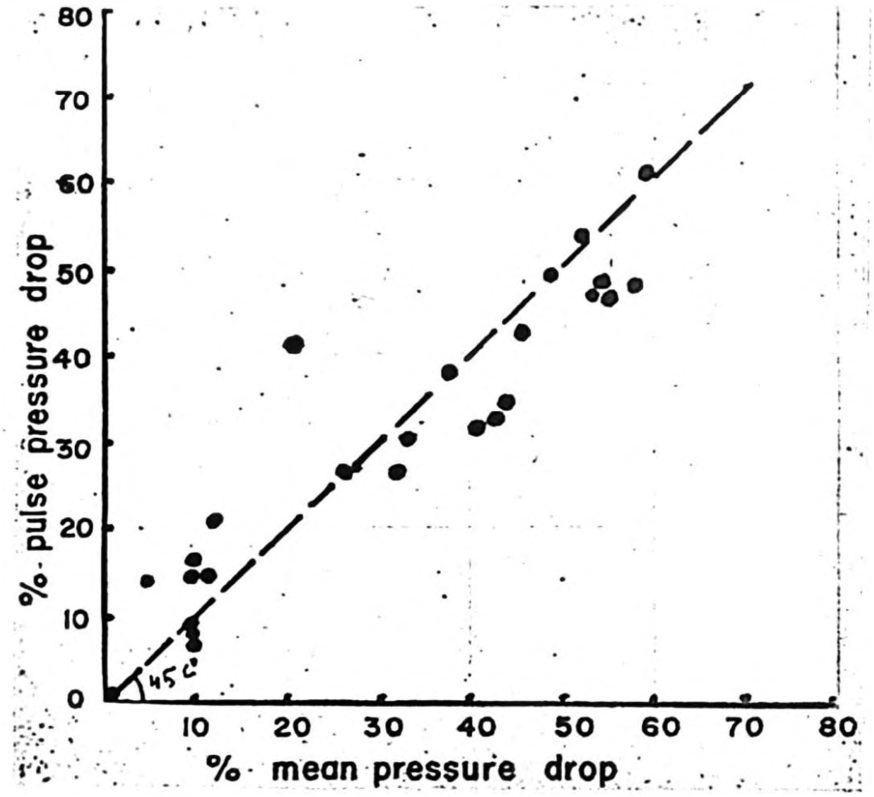


Fig. 3. — Relationship of mean and pulse pressure decreases following certain occlusions.

communicating vessels of 1 mm. diameter, the pressure drop in the internal carotid was 47 per cent, in the middle cerebral 51 per cent and in the anterior cerebral 46 per cent. In the posterior cerebral a 6 per cent drop was recorded. When the diameter of the communicating arteries was 0.7 mm., the internal carotid showed a 77 per cent decrease. The degrees of pressure decrease in the middle cerebral and in the anterior cerebral were 80 and 64 per cent respectively. With this kind of communicating system no measureable pressure changes were observed in the posterior cerebral.

Occlusion of Vertebral Arteries: Pressure decreases with unilateral vertebral ligations have not been affected by the size of the posterior communicating arteries. In the posterior cerebral (fig. 6 B), superior cerebellar and basilar arteries, 10 per cent pressure decreases have been recorded after unilateral vertebral occlusion. In the vertebral system, contrary to the carotid system, recordings made at the proximal ends have shown greater pressure drops. Thus, after ipsilateral vertebral occlusion, the pressure drop in the distal portion of the vertebral artery was 12 per cent but in the proximal portion this drop was increased to 21 per cent (fig. 7 A, B). Occlusion of the contralateral vertebral artery causing about the same amount of pressure drop in the distal portion

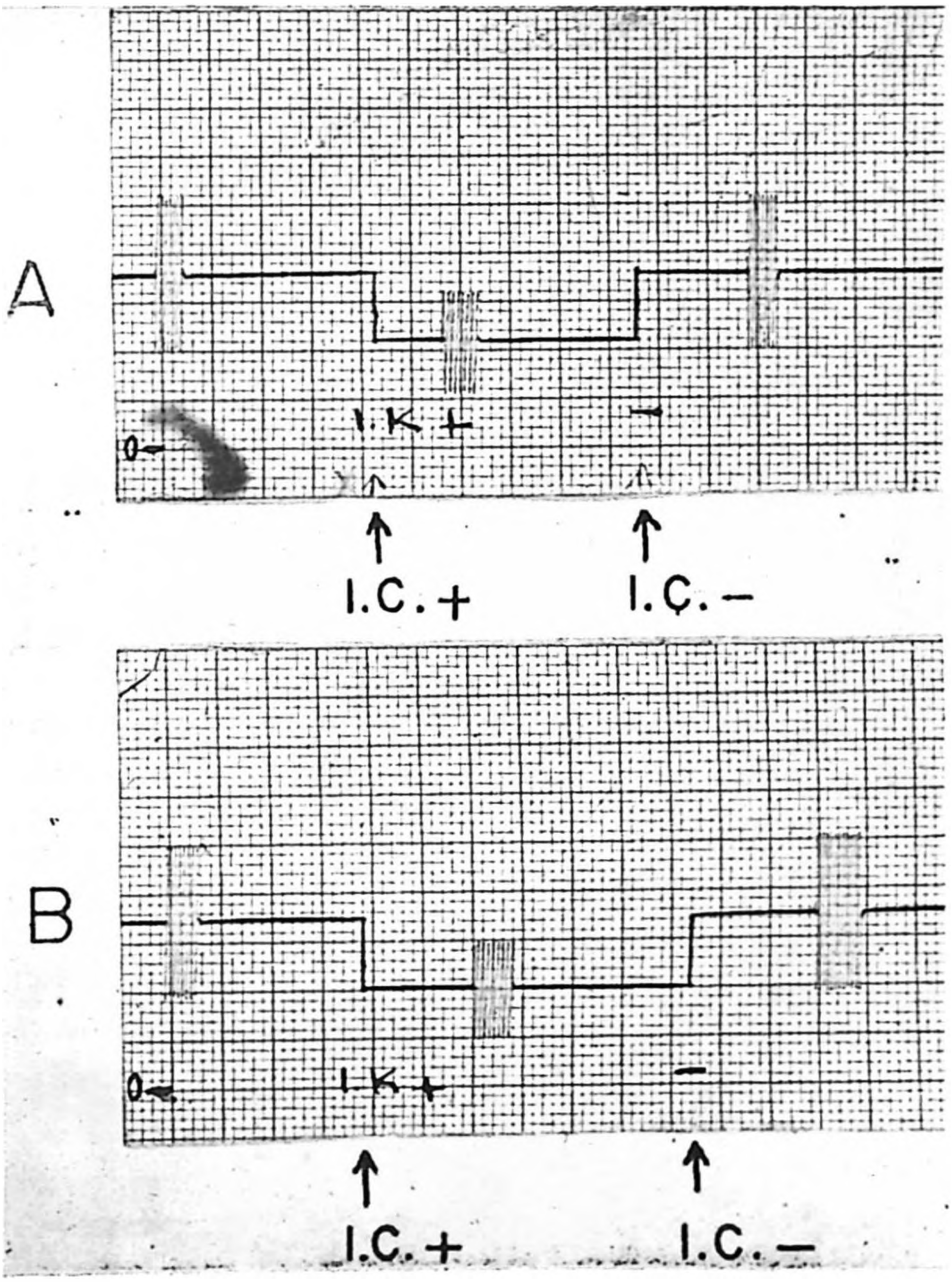


Fig. 4. — A. Pressure drop in the carotid artery after proximal occlusion of this vessel. B. Pressure changes in the middle cerebral artery after carotid occlusion.

of the vertebral and in the posterior inferior cerebellar arteries was another important finding. At the same time in the proximal portion of the vertebral only a 2 per cent drop was recorded.

As expected, the pressure decreases following bilateral vertebral occlusions depended on the size of the posterior communicating vessels. Here also, a single ligation is made of the vertebral artery, the fall in pressure is progressively less as readings are taken at progressively greater distances distal to the occlusions. When the posterior communicatings were 1.5 mm. in diameter, observed pressure decreases were in the posterior cerebral (fig. 6 C), and in the superior cerebellar 45 per cent, in the basilar 53 per cent and in the proximal vertebral arteries 59 per cent.

When one of the vertebrals was reduced to a third of its normal size (1 mm.), occlusion of this vessel caused only a 7 per cent pressure

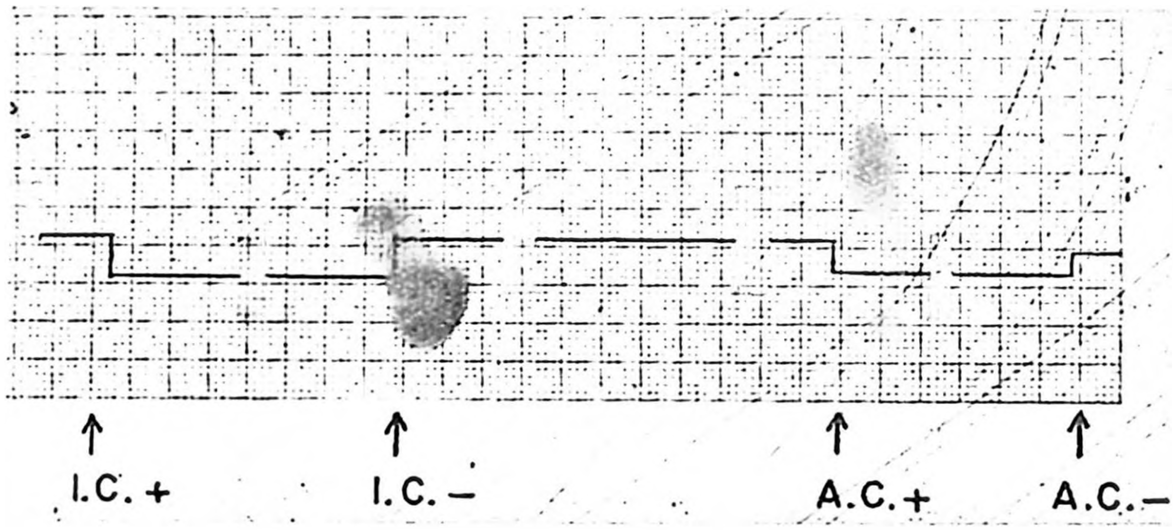


Fig. 5. — Pressure changes in the anterior cerebral artery after carotid and proximal anterior cerebral artery occlusion.

decrease in the posterior inferior cerebellar artery instead of 12 per cent as in normal conditions. If the contralateral vertebral artery was reduced to 1 mm. in diameter, occlusion of a normal sized vertebral gave a 42 per cent mean pressure decrease in the ipsilateral posterior inferior cerebellar artery (fig. 8 A, B, C).

Proximal Anterior Cerebral Occlusions: Here the results depended on the size of the anterior communicating and proximal anterior cerebral arteries. When the anterior communicating artery was 1.5 mm. in diameter, a 25 per cent pressure drop was observed in the anterior cerebral artery after proximal occlusion of this vessel. A 75 per cent drop was recorded in the anterior cerebral artery if the diameter of the anterior communicating artery was reduced to 0.7 mm. When one of the proximal anterior cerebrals was reduced in length to one half of the other, the pressure decrease was even less than that which was recorded under normal anatomical conditions.

With a communicating artery of 1 mm. in diameter, occlusion of the small proximal anterior cerebral gave a 23 per cent pressure decrease in the ipsilateral anterior cerebral (with a normal size proximal anterior cerebral a 31 per cent drop was recorded).

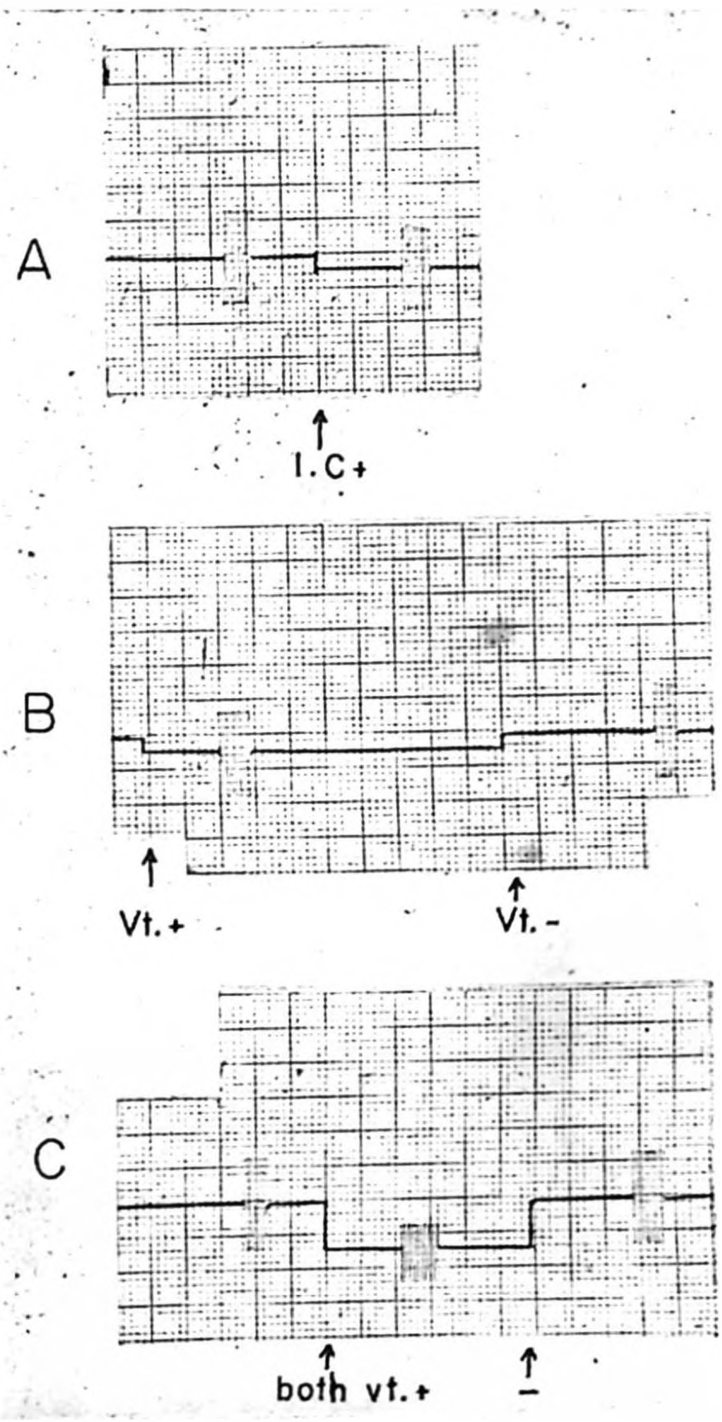


Fig. 6. — A. Pressure changes in the posterior cerebral artery after carotid occlusion.

B. The same pressure decrease occurred in the posterior cerebral following unilateral vertebral occlusion.

C. Pressure decreases in the posterior cerebral after bilateral vertebral occlusion.

Discussion

The studies of clinical workers have shown that a 30 to 70 per cent mean pressure decrease occurs in the intracranial portion of the internal carotid artery following internal carotid occlusion in the neck. In some cases a return of this pressure drop to the normal level has been observed when the measurements were repeated at a later date. This was believed to be due to the development of

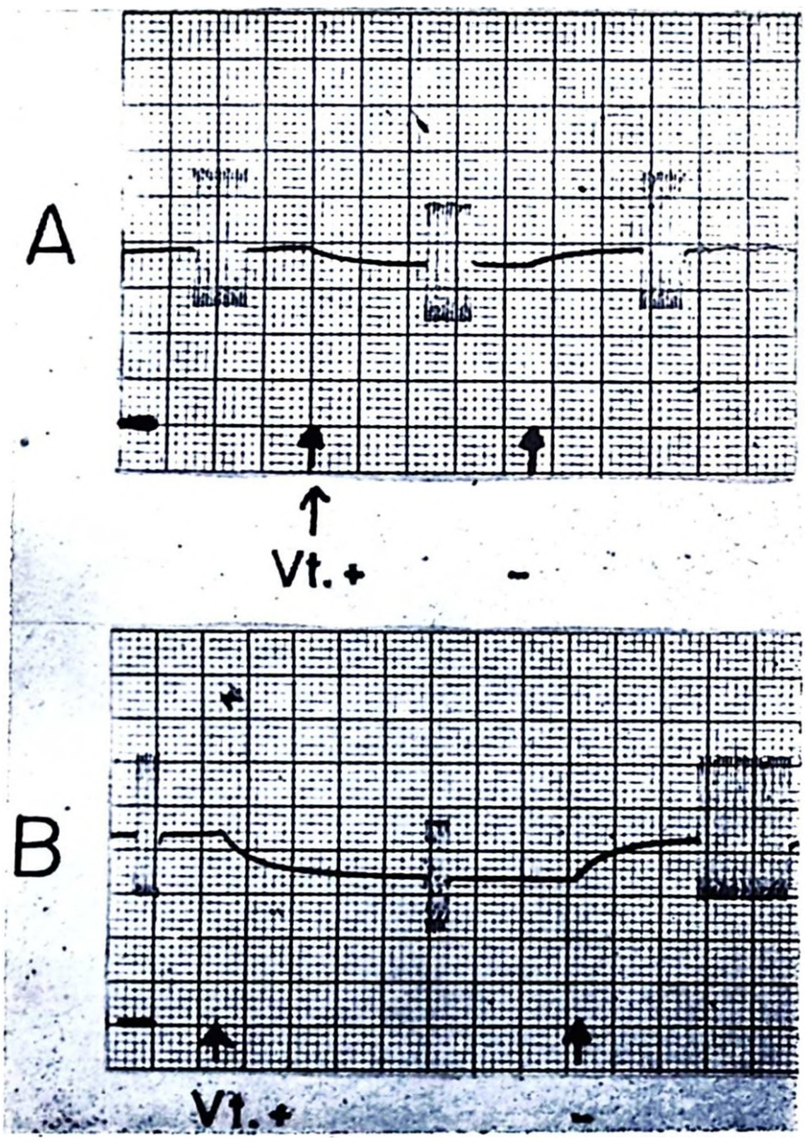


Fig. 7. — Pressure changes in the distal and proximal portions of the vertebral artery after ipsilateral vertebral occlusions.

collateral circulation through the external carotid and cortical communicating vessels. At present it is commonly believed that in most cases the obtained pressure drop will remain for a considerable time. The impressively good results which have been obtained with carotid ligations on the treatment of internal carotid aneurysms also supports this viewpoint. With different types of communicating arteries, about the same amount of pressure decrease was noted; the plastic model appears to be a reliable tool to study the dynamic characteristics of the cerebral arterial system. It should be pointed out that the model does not have the collateral vessels and the results only represent acute changes. Anterior communicating aneurysms,

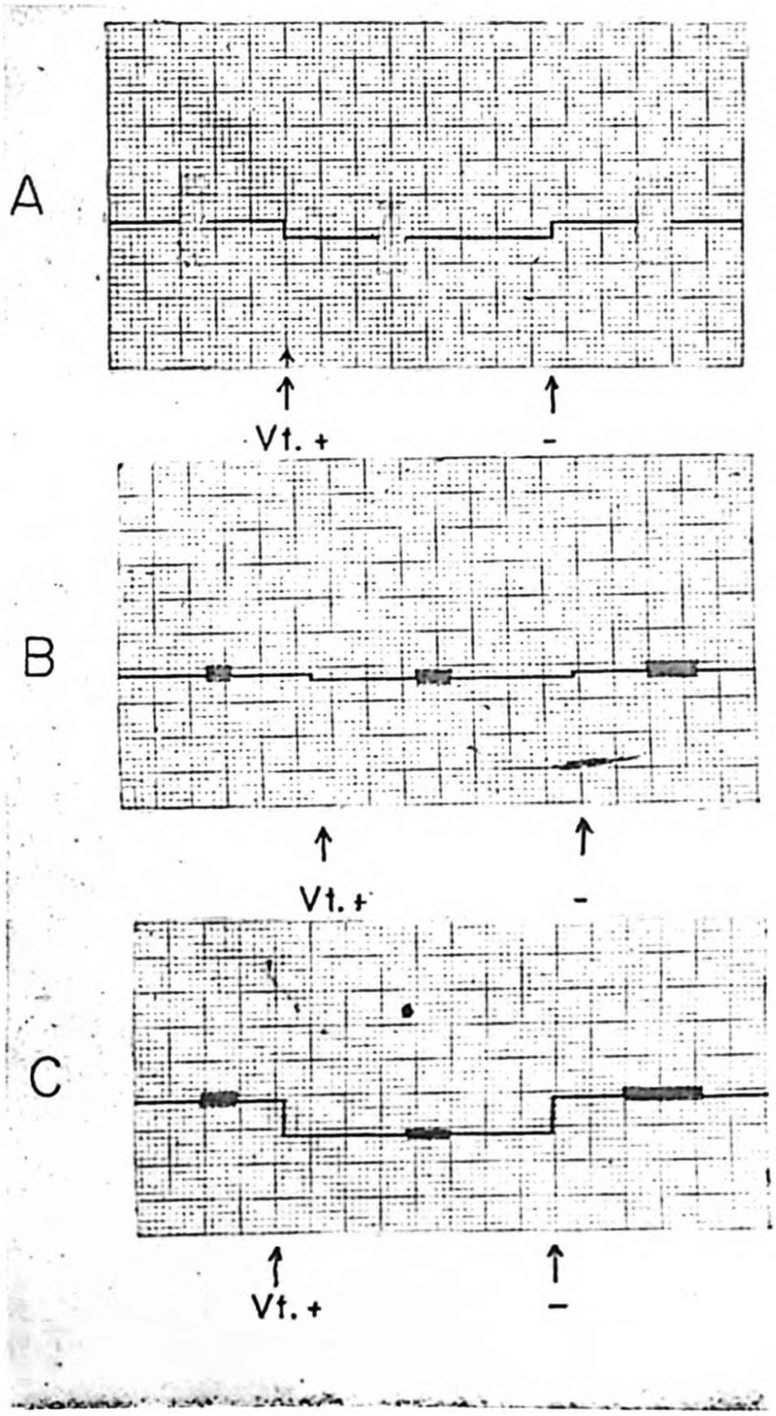


Fig. 8. — Pressure changes in the posterior inferior cerebellar artery following the occlusion of the ipsilateral vertebral artery.

according to the results obtained from the model, will not benefit from proximal anterior cerebral ligations in most cases. The amount of the pressure drop is not too significant with anterior communicating arteries of normal size. With a small (0.7 mm. in diameter) anterior communicating, even a clinically dangerous 75 per cent decrease was observed. An important consideration would be the measurement of the pressure in the anterior cerebral artery before and after temporary occlusion of the proximal anterior cerebral before deciding whether direct attack by ligation of the ipsilateral proximal anterior cerebral is indicated. One might question the danger of puncturing a small vessel like the anterior cerebral. Woodhall and others have studied the effect of puncturing the cerebral vessels with small calibre needles. When a number 27, was used, no complications occurred even in the cortical vessels.

Middle cerebral aneurysms have been treated by carotid ligations but results have not been satisfactory. [2,12,13] About the same amount of marked pressure decrease was observed in the middle cerebral artery in the model. A possible explanation for this is that in the peripherally situated middle cerebral aneurysms the return of the decreased pressure might occur rapidly. This has not been shown clinically and deserves attention. On the other hand cortical blood flow studies have shown that cortical blood flow reaches the normal level after a few minutes following carotid occlusion in the neck. [14,15] Since flow and pressure have a linear relationship, one would expect the return of the pressure to normal levels in the cortical vessels in a short time after occlusion of the major cerebral vessels. This is probably the main reason why ligations have little value for the treatment of peripherally situated vascular lesions. Posterior cerebral artery aneurysms should not be treated with carotid or unilateral vertebral ligations since occlusion of both arteries only gives a 10 per cent pressure decrease. Falconer [13] has treated a posterior cerebral aneurysm with ipsilateral vertebral ligation and apparently a good clinical result has been obtained. This is the only reported case in the literature with ligation, and neither the size of the vertebrals nor the pressure measurements were reported. Moreover, it would be unwise to draw a conclusion from a single case. Posterior fossa aneurysms will also obtain little benefit from unilateral vertebral occlusions if both vertebrals have about the same diameter. Hutchinson and Yates [16] have found that the vertebral arteries differed in 92 per cent of human autopsies. This is a great percentage and means that most of the cases, after unilateral vertebral ligations, show either very insignificant pressure drops as measured by Bakay and Sweet, [6] or marked decrease of the pressure in the vertebral tree, as was observed by others. [11,17].

Again here in the vertebral system only direct pressure measurements would give the best idea as to whether ligation of the vertebral artery has any value. Because of the great percentage of variation of the vertebral arteries in this system much more variable results should be expected.

Summary

A plastic model of the cerebral arterial tree was made and the hemodynamic changes were studied after certain occlusions. Because of technical difficulties, clinical workers have not been able to investigate these changes in man satisfactorily. The results have been given and their clinical significance has been discussed.

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