CAROTID-INTERNAL JUGULAR ANASTOMOSIS
IN THE RHEUS MONKEY

ANGIOGRAPHIC AND GASOMETRIC STUDIES*

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Arteriovenous anastomosis between the carotid artery and the external jugular vein was performed by Gluck in 1896. In 1902, Carrel and Morel anastomosed the carotid artery to the external jugular vein in the dog. Later, in 1907, Watts made pathological studies of the external jugular vein through which carotid arterial blood had traversed. Carrel suggested that such an anastomosis may “increase the circulation of the brain by directing a strong current of red blood through the internal jugular vein in dogs, the peripheral end of this vein being anastomosed through a central end of the common carotid artery.” He quoted Jaboulay, who in 1902 had expressed the opinion “that an arteriovenous anastomosis might have a good result in case of insufficient circulation, as in softening of the brain.” Carrel did not believe that such a lesion could be successfully treated but stated that “it is not absolutely improbable that the slow and progressive disease of cerebro-sclerosis might be benefited by an operation modifying the circulation.”

Carrel noted that when arterial blood was shunted into a vein, the vein wall rapidly thickened. The degree of thickening depended upon the amount of increase in the blood pressure. If the vein was required to support the normal arterial pressure, extensive thickening resulted with eventual complete obliteration of the lumen. Carrel found after the production of a shunt that “no clinical troubles occur in the dog; a dog operated on five months ago is living in good health.” It is doubtful that arterial blood ever reached the brain in these animals even though the shunt may have been functioning. If the external jugular were used for such an anastomosis most of the blood would be shunted into the veins of the neck rather than into the cranial cavity.

Beck, McKhann, and Belnap have reported upon common carotid-internal jugular anastomosis in the neck with ligation of the distal end of the internal jugular vein, as a means of revascularization of the human brain. A side-to-side anastomosis of the common carotid and internal jugular has been done and in later operations the external carotid and the internal jugular have been anastomosed. After the anastomosis an increase in the blood flow through the head was noted by utilizing a technique of tracing

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radioactive material injected into the circulation and gasometric studies of oxygen in the sagittal sinus before and after a shunt.

In order to evaluate critically carotid and internal jugular shunts, experiments have been performed on rhesus monkeys. Two fundamental factors have been studied and are discussed in this paper. (1) The direction of the flow of blood after the shunt. (2) The oxygen content of the blood in the sagittal sinus before and following the shunting procedure, studied by gasometric methods.

MATERIAL AND METHODS

The use of the dog as an experimental animal in this type of research is unsatisfactory since the internal jugular in this animal is small or absent and the external

![Fig. 1 (left). Angiogram of rhesus monkey after carotid-internal jugular shunt (5 cc. of 35 per cent diodrast injected). The diodrast goes up one jugular to the lateral sinus on the same side, thence to the opposite lateral sinus and down the other jugular in the neck. Note also that there are many other neck communications.

Fig. 2 (right). Angiogram of a shunted rhesus (5 cc. diodrast). Note that the internal jugular has extensive neck communications, although some of the diodrast reaches the intracranial space and enters the lateral sinus in the head.

jugular has extensive extracranial tributaries. The rhesus monkey, on the other hand, is suitable since the internal jugular vein and its communication with intracranial venous pathways is similar to that in the human (Figs. 1–5).

Thirty-eight animals were experimented upon. Intravenous Nembutal (1 gr./5 lbs. body weight) was used for anesthesia in all experiments.

In 11 animals angiograms were obtained after the shunt. Five cc. of 35 per cent solution of diodrast was used for visualization of the shunted pathways. Angiograms were obtained under varying conditions, including ligation of other veins on the neck such as the opposite jugular, external jugular and other neck tributaries; obstruction of both carotid arteries and ligation of the opposite lateral sinus. The pressure of the diodrast injection was measured in some experiments.

In 17 monkeys gasometric studies of oxygen content were made by the Van Slyke technique. Artificial respiration with intratracheal oxygen was used with 16
Fig. 3. A human left internal jugular venogram (20 cc. of 85 per cent diodrast injected by the open method). Note that the diodrast was directed up to the lateral sinus to the opposite lateral sinus and down the opposite jugular vein. There are intercommunications between the jugulars in the neck. The intracranial distribution of the diodrast is very similar to Fig. 1, a monkey angiogram.

strokes and 3 l. oxygen/min. During these procedures, which lasted between 2½ to 4 hours, there was a decline in the oxygen tension in spite of artificial respiration with 100 per cent oxygen. However, in spite of this difficulty the figures are convincing (Table 1). In most animals a side-to-side anastomosis was used. In a few, an end-to-end shunt was utilized. Anastomoses were made on the right and left side in almost equal numbers. As shown in Table 1, specimens were obtained from the femoral artery, superior sagittal sinus, and the contralateral jugular before the shunt and after the shunt. Since these animals weighed from 8 to 10 lbs., it was not possible to obtain specimens from all of these vessels in the same animal, because of serious reduction of blood volume. However, in all animals the sagittal sinus blood oxygen content was studied before and after the shunt and arterial blood levels were established in most experiments and in others the oxygen content of the contralateral jugular before and after the shunt was obtained.

RESULTS

The angiographic studies revealed two patterns of flow of the shunted arterial blood. (1) The flow may reach the lateral sinus on the ipsilateral

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<th>Rhesus No.</th>
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<th>Contralateral Jugular</th>
<th>Femoral Artery</th>
<th>Sup. Sagittal Sinus</th>
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TABLE 1

Oxygen tension in volume per cent of oxygen
side, then course downward through the contralateral sinus into the neck veins. (2) The course may be upward in the jugular vein, to be dispersed through the basilar and neck tributaries (Figs. 1 and 2). The ligation of contralateral jugular vein or venous tributaries in the neck did not direct the flow into the intracranial venous system other than the lateral sinuses.

Angiograms obtained in shunted animals after ligation of the opposite lateral sinus revealed that the lateral, the superior sagittal, the inferior sagittal and tributaries of the cerebral cranial venous system were injected (Fig. 8). Such filling was possible only when injections of the diodrast in 5 to 10 cc. amount were administered with pressures well over 150 mm. of mercury (Fig. 6).

In Table 1, the gasometric studies of 8 animals are given. The oxygen content of the sagittal sinus blood decreased after the shunt was established. While the sagittal sinus values were quite low, the contralateral jugular vein oxygen content was indisputably high. The oxygenated blood became distributed in the neck veins. Ligation of the opposite lateral sinus did not result in an increase of oxygen content of the sagittal sinus blood. In this group of animals the sagittal sinus oxygen values were again uniformly decreased after the shunting (Rhesus No. 36, 37, Table 1).

![Fig. 4 (left). Injection of 20 cc. of 35 per cent diodrast by the open method into left internal jugular vein in the human. In the anteroposterior view the left jugular becomes continuous with the left lateral sinus and this in turn seems to be continuous with the sagittal sinus. This is different than the usual pattern of superior sagittal sinus being continuous with the right lateral sinus. Lateral view is shown in Fig. 5.](image1)

![Fig. 5 (right). Injection of 25 cc. diodrast into left internal jugular vein. The diodrast traverses up the jugular into the lateral sinus on the one side to the opposite lateral sinus and then down the neck in the internal jugular on the opposite side. There are many neck communications. A portion of the diodrast is seen extending up toward the superior sagittal sinus without entering same.](image2)
CAROTID-INTERNAL JUGULAR ANASTOMOSIS

Fig. 6 (left). Angiogram after right common carotid-internal jugular fistula (20 cc. of 35 per cent didodrast). The dye goes up into the lateral sinus with no dye in the sagittal sinus (human).

Fig. 7 (right). Angiogram after right common carotid-internal jugular anastomosis (20 cc. of 35 per cent didodrast injected). The dye goes up the jugular to the lateral sinus on the same side, thence to the opposite lateral sinus. No dye is seen to enter the superior sagittal sinus. When the dye is injected into the common carotid artery immediately after completion of the shunt, the internal carotid and its branches, as well as the internal jugular and the lateral sinuses, are visualized.

Fig. 8. Anteroposterior and lateral views of rhesus with right carotid-internal jugular fistula. The left lateral sinus was ligated. Note that the superior and inferior sagittal sinuses and cerebral tributaries are now visualized.

CONCLUSIONS

In acute experiments with the rhesus monkey after a carotid-internal jugular shunt, the blood does not flow into the sagittal, straight or petrosal sinuses for distribution by retrograde flow. Instead, it seeks a ready exit via the neck veins, the basilar veins and the lateral sinuses. Angiographic studies
show that the shunted flow can be directed into the intracerebral veins by ligation of the opposite lateral sinus and diodrast injection under pressure well above the systolic arterial pressure. As pointed out, among the animals with the opposite lateral sinus ligated, the oxygen volume per cent of the sagittal sinus blood did not become increased.

There appears to be a stagnation of the blood in the sagittal sinus after the shunting as shown by oxygen determinations in acute experiments. The lowered oxygen values in the sagittal sinus occurred in the presence of elevation of oxygen content of the neck veins, thus confirming the angiographic patterns.

REFERENCES

3. Gluck. Quoted by Watts.6