THE SIGNIFICANCE FOR THE CEREBRAL BLOOD SUPPLY OF ANASTOMOSES BETWEEN THE BRANCHES OF THE EXTERNAL AND INTERNAL CAROTID ARTERIES

A. M. Blinova, and N. M. Ryzhova

Laboratory of the Physiology and Pathology of Respiration and Circulation
(Head, Corresponding Member AMN SSSR Prof. M. E. Marshak) Institute of Normal
and Pathological Physiology (Director, Active Member AMN SSSR V. V. Parin) AMN SSSR, Moscow
(Presented by Active Member AMN SSSR V. V. Parin)
Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny Vol. 52, No. 8
pp. 3-8, August 1961
Original article submitted September 15, 1960

There are several specific anatomical features of the blood supply to the brain. One is that there are anastomoses between the branches of the external and internal carotid arteries, which are particularly well developed in dogs and cats [5, 7, 11, 14]. In dogs the principal anastomoses are the orbital branch of the internal maxillary artery and the branch of the median meningeal artery, which originate from the internal carotid artery within the skull. In experiments in which the brain was perfused through these anastomoses only, S. Bukart and S. Heymans found that sufficient blood was supplied to maintain function in the brain centers. They also found that when the internal maxillary artery was ligatured below the anastomotic branches, the flow along the internal carotid artery was increased and the tissues of the head whose blood supply had been cut off were therefore supplied through the anastomoses. Because of this result, many investigators [2, 13 and others] attribute great significance to these anastomoses in regulating the blood supply to the brain during reflex responses in general, when there is a change in the extracranial vascular tone. Thus, according to Heymans [13], in hypotension, there is a reflex constriction of the extracranial vessels which originates from the sinocarotid and aortal reflexogenous zones, and blood is displaced along the anastomoses towards the brain. In hypertension, on account of a reflex dilatation of the extracranial vessels, there is a shift of blood from the same zone along the anastomoses from the brain to vessels supplying other parts of the head.

This displacement of blood along the anastomoses must be supposed to take place only if the lumen of the arteries concerned changes passively due to alterations in arterial pressure, as Bukart and Heymans claim. However, there is a considerable amount of evidence, to which our laboratory has contributed, which suggests that active changes in the tone of the cerebral vessels occurs in response to nervous and humoral influences, and that under normal conditions [4, 8, 10, 15] the blood pressure is not of great significance.

The shift of the blood along the anastomoses may also take place if the active change in the tone of the cerebral vessels associated with a reflex response opposes that of the extracranial vessels; however, many experiments have been done in which the cerebral and extracranial circulations have been isolated, and it is found that in most cases the response of the extracranial vessels and those supplying the brain are usually the same when evoked by various influences which bring about a reorganization of the circulation. They are somewhat better shown in the extracranial circulation [1, 6, 9 and others]. These quantitative differences may establish conditions which bring about a shift of blood between the cerebral and extracranial circulations. Whether or not such a change occurs under normal conditions can be determined only by experiment.

In the present work, in order to determine the part played by the anastomoses, we have studied the reaction of the extracranial and the cerebral vessels, both when the anastomoses were open and when they were closed. The same animal was used for a number of different reflex responses.

METHOD

The work was carried out on 19 adult dogs under morphine and urethane anesthesia. We studied changes in the cerebral and extracranial blood supply before and after clamping the anastomoses during the hypoxia, hypercapnia, or stimulation of the interoceptors of the small intestine. A flat thermoelectrode [3] was used to record blood flow in the parietal meninges; the rate of flow in the external carotid artery was measured by means of a Hoičns type thermoelectrode; the arterial pressure in the femoral artery was measured by a mercury manometer, and the respiratory movements were recorded by a pneumograph. Photographic records of all these quantities were made simultaneously.

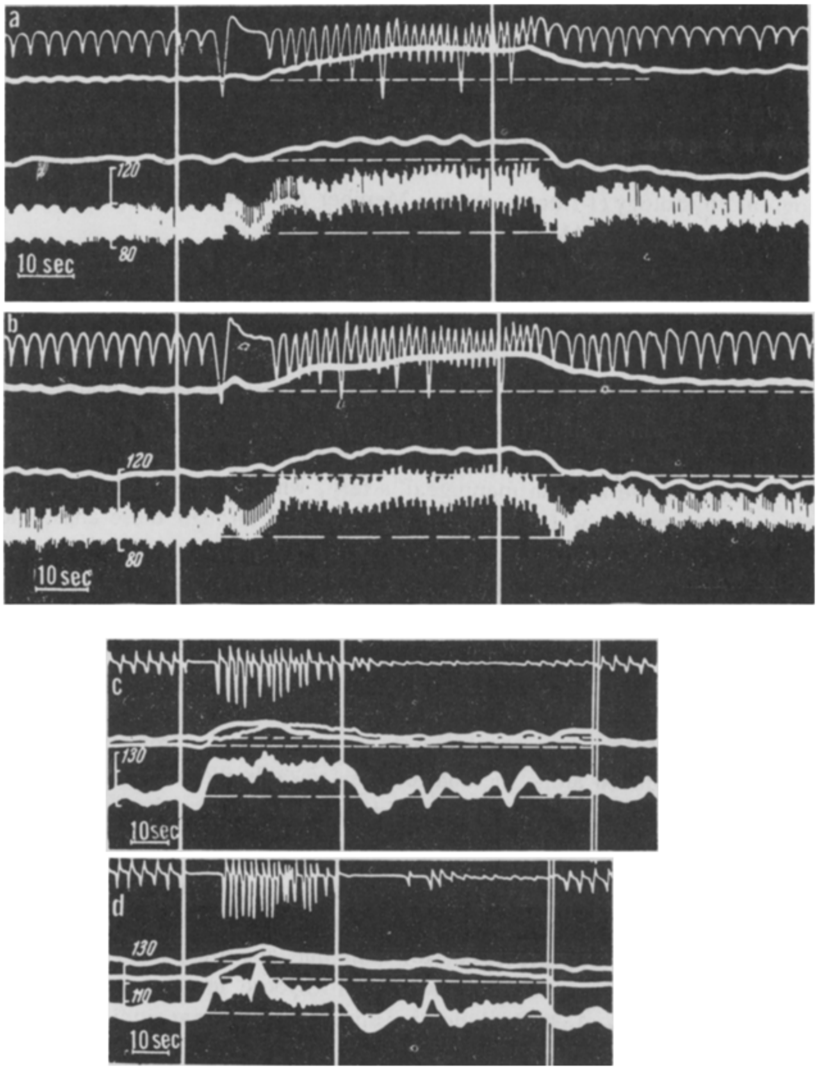

Fig. 1. Reaction to hypoxia and to stimulation of the small intestine. a) Reaction to hypoxia, before compressing the anastomoses; b) reaction to hypoxia, after compressing the anastomoses; c) reaction to stimulation of the interoceptors before compression of the anastomoses; d) response to stimulation of the interoceptors after compressing the anastomoses. Curves, from above downwards; respiratory movements; blood flow in the cerebral meninges; blood flow in the external carotid artery; pressure in the femoral artery; ---- initial level of the quantity recorded. Vertical lines indicate the beginning and end of the applied stimulus.

To clamp the anastomoses, we made an approach from the base of the skull. A ventral incision was made through the skin starting at the mental protuberance and continuing it to the thyroid cartilage. We exposed the digastric and mylohyoid muscles on both sides and all vessels between them were carefully ligatured. The muscles were separated with a retractor; the external pterygoid muscle was then exposed, separated at its point of attachment to the crest of the pterygoid bone opposite the articulation of the lower jaw by means of a thermocautery, and then folded back laterally. Beneath this muscle on the surface of the articular process of the lower jaw we exposed and dissected out the internal maxillary artery close to its entry into the pterygoid bone. We passed a ligature beneath it. Then 0.8-1 cm rostrally we separated the fibers of the external and internal pterygoid muscles and found the edge of the canal where the internal maxillary artery emerges. From where it emerged it was dissected out for 5-6 mm rostrally, and a ligature was placed beneath it so as to enclose the orbital artery with its anastomosing branch. The ends of both ligatures were brought out into the apertures at the base of a polyethylene cylindrical tube 3 mm in diameter and 3 cm long, and were fixed with a cork to its outer opening. The artery was clamped by pulling on the ends of the ligatures which were brought out from the tubes. At the end of the experiment we confirmed that the arteries had been completely tied off. Deep illumination was necessary for a satisfactory preparation to be made.

RESULTS

Bilateral compression of the anastomoses by pulling on the ligatures caused either a small reduction or an increase in the flow in the cerebral meninges. The change was shortlasting, and was apparently due to a pain reaction induced by compression of the vessels. This effect was signalled sometimes by movements of the animal and some increase in arterial pressure. After only 30-60 seconds, the blood flow returned to the original level obtaining before tying off the anastomoses. At the same time the flow in the external carotid artery was noticeably reduced, and remained reduced for the whole time the anastomoses were clamped; this effect results from cutting off some of the vascular branches above the point where the internal maxillary and orbital arteries were clamped.

Hypoxia was induced by causing the animal to breathe a mixture of 6-7% oxygen from a Douglas bag. Under normal experimental conditions, when the anastomoses are open, hypoxia increases the rate of flow in the extra- and intracranial circulations, as can be seen from Fig. 1, a. The reaction was the same in its magnitude and direction after compressing the anastomoses (Fig. 1, b).

The receptors of the small intestine were stimulated by inflation with air to a pressure of 70-80 mm mercury. When the anastomoses were open, inflation caused an increased flow in the meninges and in the external carotid artery (Fig. 1, c). In most cases, compression of the anastomoses did not affect the response, but sometimes there was a rather greater increase in flow in the external carotid artery, while the increase in the meninges flow was not as great (Fig. 1, d).

According to may investigators, hypercapnia, induced by causing an animal to breathe air containing an excess of CO_2 increases the blood supply to the brain. As far as the extracranial vessels are concerned, according to Green and his co-workers [12], who perfused the external carotid artery, breathing a mixture of 10% CO_2 and air causes no change in the vascular tone of these tissues. On the other hand, A. A. Kedrov and A. I. Naumenko [1] found that under normal circulatory conditions, asphyxia increases blood flow to the extracranial tissues, an effect which they attribute to the action of the excess CO_2 in the blood. In our experimental conditions, when the anastomoses were open, breathing a mixture of 6-7% CO_2 always increased the flow in the cerebral meninges, while in the external carotid artery there was either a small decrease in the rate of flow, or no change (Fig. 2, a, c).

After bilateral compression of the anastomoses, in most cases the response to excess of CO_2 showed no change, either in the cerebral meninges or in the extracranial vessels (Fig. 2, b); however in some experiments, there was some smaller increase in the meningeal flow, and a more marked decrease of the flow in the external carotid artery than there had been when the anastomoses were open (Fig. 2, d).

Therefore, during general reflex reorganization of the circulation resulting from hypoxia, hypercapnia or stimulation of the intestinal interoceptors, the nature of the changes in blood flow to the brain and extracranial tissues is the same whether the anastomoses are open or closed. The magnitude of the change also remains the same, though in certain experiments, the response was somewhat smaller in the meninges when the anastomoses were clamped, and somewhat greater in the extracranial vessels. Jewell showed that the anastomoses may be developed to a greater or less extent in different dogs [14]. This result could explain the fact that in rare cases it is possible to observe small movements of blood along the anastomoses between the extra- and intracranial vessels. Even during reverse changes of the blood flow in the extra- and intracranial vessels, the amount of blood is not great, and has little effect on the blood supply of the brain.

Movement of the blood along the anastomoses may be very important during obstruction or ligature of the external or internal carotid arteries. Large amounts of blood may pass along the anastomoses to supply the tissues which have been deprived of their normal circulation. This circumstance must be taken into account when con-

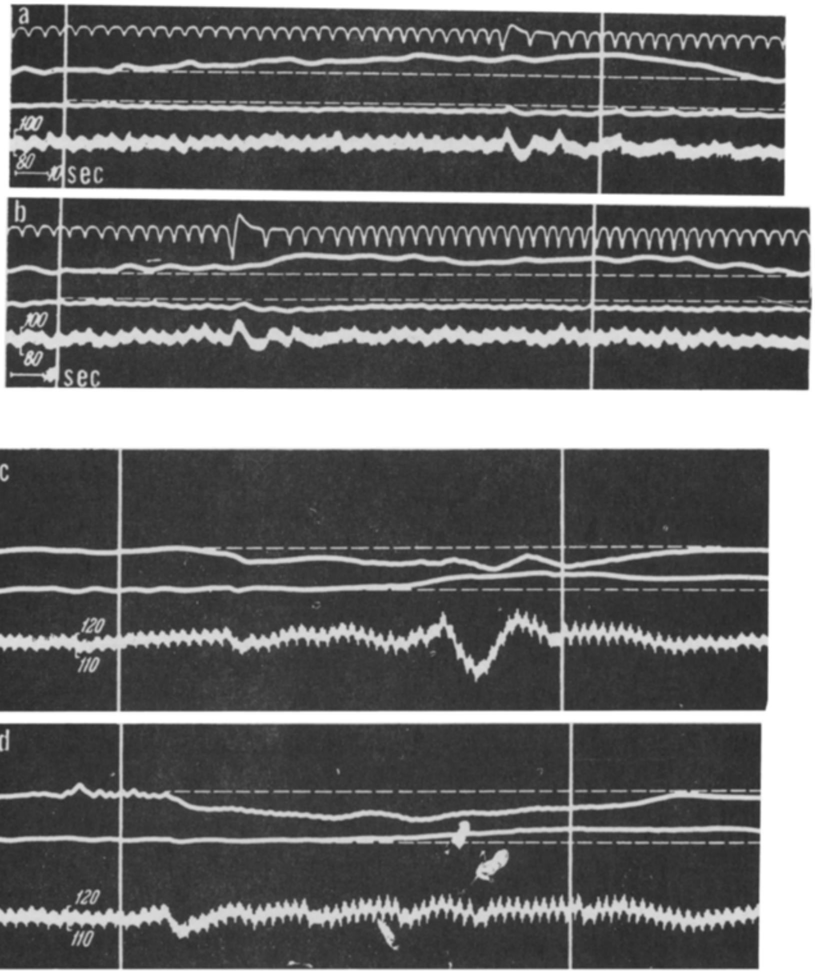

Fig. 2. Reaction to hypercapnia. a,c) Before compressing the anastomoses; b,d) after compressing the anastomoses. Curves as in Fig. 1.

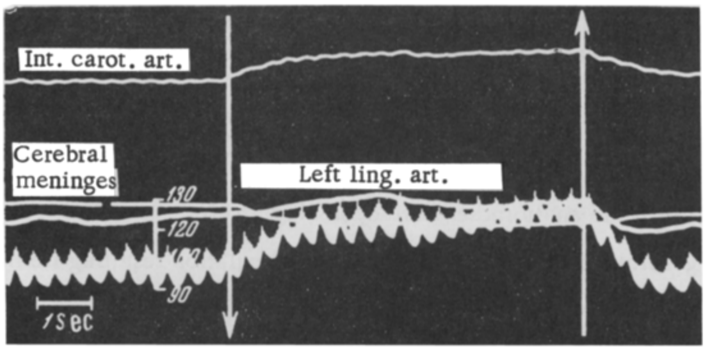

Fig. 3. Reaction to clamping the common carotid artery after ligature of the extracranial vessels. In the dog, the left carotid sinus was denervated and all the large vessels leaving it were ligatured except for the internal carotid artery; on the right hand side all the large vessels leaving the right carotid sinus were ligatured; the innervation was left intact. Curves, from above downwards: blood flow in the left internal carotid; ditto in the left lingual artery; ditto in the cerebral meninges; pressure in the femoral artery; ↓↑ –beginning and end of clamping the common carotid artery.

sidering cerebral circulations, otherwise mistakes can be made. Thus, Bukart and Heymans [7, 13] talk about the passive increase in the cerebral blood supply during the carotid reflex, and base their statement on the fact that in a dog in which the external carotid arteries have been ligatured the flow along the internal carotid artery increases when pressure in the carotid sinus falls. However, under these conditions, the flow along the internal carotid will represent the blood supply not only of the brain, but also of the extracranial tissues which are now supplied by backflow through the anastomoses from the internal carotid artery. This is shown by the results of our experiments, which we carried out under the same conditions as the experiment referred to; we recorded blood flow, not only in the internal carotid artery, but also in the meninges and in one of the branches of the external carotid artery. It can be seen from Fig. 3 that when the carotid artery is clamped, the flow through the meninges is not increased, but rather decreased through constriction of the vessels, while passive recovery of the flow occurs only in the vessels supplying the extracranial tissues.

In assessing the results it must be remembered that under normal conditions, during reflex changes of the whole circulation, the passage of blood along anastomoses does not determine the blood supply to the brain; however, when there is an obstruction or a ligature of one of the anastomosing vessels, the anastomoses critically affect the blood supply to the tissue in the region supplied by branches of the obstructed vessel.

SUMMARY

A study was made of the blood supply to the brain and the extracranial tissues in hypoxia, hypercapnia and during stimulation of the intestinal interoceptors; measurements were made before and after occluding the anastomoses. The blood flow was recorded on a photokymograph. Simultaneous recordings were made, by a thermoelectric method, of the blood flow in the meninges and anterior carotid arteries, and of the arterial pressure and respiration. The results have shown: a) That occlusion of the anastomoses does not affect the cerebral blood supply, and b) that in reflex reactions of the general circulation, the nature and extent of the changes in blood flow in the extra- and intracranial vessels were nearly the same whether the anastomoses were intact or occluded. Even when there was a backflow of blood in the extra- and intracranial vessels, occlusion of the anastomoses had but little effect upon the cerebral blood supply.

LITERATURE CITED

1. A. A. Kedrov and A. I. Naumenko, Problems of the Physiology of the Internal Circulation and Their Clinical Interpretation [in Russian] (Leningrad, 1954).
2. B. N. Klosovskii, The Cerebral Circulation [in Russian] (Moscow, 1951).
3. M. E. Marshak, Byull. Eksptl. Biol. i Med., 43, 1, 121 (1957).
4. N. M. Ryzhaov, Byull. Eksptl. Biol. i Med., 2, 13 (1957).
5. E. S. Yakovleva, The Development of the Internal Carotid Artery and the Rete Mirabile of the Base of the Skull of Certain Mammals. Candidates dissertation [in Russian] (1947).
6. L. Binet and M. Burstein. C. R. Soc. Biol. 147 (Paris 1953) p. 220
7. J. J. Bouckaert and C. Heymans. J. Physiol 79 (London 1933) p.49; 84 (1935) 367.
8. A. Carlyle and J. Grayson. J. Physiol 133 (1956) p. 10.
9. J. Finesinger and T. J. Putnam. Arch. Neurol. Psychiat. 30(1933) p. 775
10. H. S. Forbes, G. I. Nason and R. C. Wortman. Arch. Neurol. Psychiat. 37 (1937) p. 334
11. H. D. Green and A. B. Denison. Circulat. Res. 4 (1956) p. 565
12. H. D. Green, B. Heafner and J. T. Anderson. Am. J. Physiol. 187 (1956) p. 602
13. C. Heymans, Introduction to the Regulation of blood Pressure and Heart Rate. (Springfield, 1950).
14. P. A. Jewell, J. Anat. 86 (London, 1952) p. 83.
15. S. S. Kety, Am. J. Med., 8 (1950) p. 205.