Anatomical Studies of the Collateral Blood Supply to the Brain and Upper Extremity

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The last decade has brought a growing interest in cerebrovascular insufficiency associated with occlusion of the vertebral arteries and vessels contributing blood to these arteries. As one aspect of the problem, we have been studying the collateral circulation to determine the details of its channels of circulation and their interrelationship.

Review of Past Studies

Consideration has been given in the literature to such factors as lesions in the cervical vertebrae, head movements, and anatomical variants; the incidence and character of angiographical changes have also been carefully analyzed. Detailed descriptions have been given of the clinical forms of these circulatory disturbances. Attention has been called to the "subclavian steal syndrome." Further clinical studies have been stimulated by the development of surgery of the blood vessels leaving the aortic arch. De Bakey, and others reported endarterectomies performed on the common and internal carotid, vertebral, and subclavian arteries, and brachiocephalic trunk.

The inconsistencies noted between the clinical picture, angiographic changes, and the autopsy findings are interesting. It is obvious that the various clinical pictures encountered may be conditioned by a related variety in the sites of the occlusive lesions. This, however, does not explain the variety of clinical syndromes that occur with the identical sites of occlusion. The role of compensatory factors should not be underestimated, and attention to the problem of collateral circulation seems justified.

In postmortem investigations, Schultze and Sauerbrey showed that the anastomoses between the occipital artery and vertebral arteries are constant. The presence of these connections has also been proved in angiographical examinations. Cooper demonstrated the connection between the superior and inferior thyroid arteries; he also demonstrated the presence of contrast medium in the vertebral artery distal to the site of the carotid or vertebral ligation. Ljubomudrow showed that possible channels of collateral circulation are the arterial branches (and their connections) of the inferior and superior thyroid, ascending and transversing cervical, superior intercostal, and posterior auricular arteries.

In 1956, Whisnant and coworkers performed similar investigations on 12 dogs, ligating the carotid and vertebral arteries. As a rule the dogs survived the operations, and some showed little sign of damage to the central nervous system. In nine other dogs, the authors tried to limit the flow of blood to the brain by ligating both vertebral arteries at the level of the transverse process of the sixth vertebra, both the common and internal carotid, vertebral, and subclavian arteries, and brachiocephalic trunk.

Postmortem examinations showed no important damage in the cerebral tissue in seven of the nine animals. Injection of contrast medium into the arterial system demonstrated the role of the internal thoracic artery and of the costo-cervical trunk as possible channels of collateral blood supply.

New data concerning the channels of collateral circulation were revealed by angiographic examinations performed in patients with occlusive lesions of vessels leaving the aortic arch and with traumatic lesions of arteries supplying the upper extremity. These examinations emphasized the following anastomo-
sic connections: between the ascending cervical and deep cervical arteries, and the vertebral artery; between the external carotid and ascending cervical arteries; between the two vertebral arteries; between the two inferior thyroid arteries; between the superior and inferior thyroid arteries; and between the two internal thoracic arteries.

In earlier studies we identified an area Szapiro calls the “anterior aorto-cerebral circle.” This area is especially important to the collateral circulation of the brain and retina. We are reporting here experiments concerned with the connections between the “posterior aorto-cerebral circle” and other vascular areas. The term “posterior aorto-cerebral circle” covers the arterial terrain bounded by the aortic arch, the right brachiocephalic trunk, the proximal portion of the subclavian arteries (Fig. 1), and the vertebral arteries joining to form the basilar artery.

**Material and Methods**

Our postmortem studies were made on patients who died of various diseases. As in the previous experiments, occlusive ligatures were placed on certain arteries and their connections to demonstrate the collateral blood circulation after injection of preserved blood or artificial materials such as synthetic latex plus Micropaque to obtain radiological verification. A total of 40 such experiments were carried out, which we divided into three main groups illustrated by Figs. 1–3.

Numbers in Fig. 1 and subsequent figures indicate the following arteries:

1. Vertebral artery
2. External carotid artery
3. Occipital artery
4. Subclavian artery
5. Thyro-cervical trunk
6. Transverse cervical artery
7. Costa-cervical trunk
8. Clamp of the brachio-cephalic trunk
9. Anterior and posterior intercostal arteries
10. Anastomoses between anterior and posterior intercostal arteries and the branches of the axillary artery
11. Axillary artery
12. Brachial artery
13. Internal thoracic artery
14. Superior thoracic artery
15. Acromio-thoracic artery
16. Lateral thoracic artery
17. Aorta
18. Ophthalmic artery.

**Results**

**Collateral Circulation Between the Vertebral Artery and the External Carotid Artery.** One group of experiments concerned circulation between the vertebral and external carotid arteries. As shown in Fig. 1 B, latex medium or preserved blood injected into the vertebral artery reached the external carotid artery and its branches, although the vertebral artery had previously been ligated intracranially. The medium also reached the subclavian artery through anastomoses between the vertebral artery and the branches of the

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**Fig. 1 A. Diagram of the posterior aorto-cerebral circle.**