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THE BLOOD SUPPLY OF THE CAROTID BODY IN CATS, DOGS AND RABBITS

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In spite of a considerable literature dealing with the reflex effects of stimulation of the chemoreceptors of the carotid body, our information about the arterial blood supply and the venous drainage of that area is surprisingly inadequate.

Schaper (1892), in his studies of the histology of the 'glandula carotica', could not detect any definite pattern in the blood supply of the carotid body. In man, he observed regularly a small artery arising from the carotid bifurcation or 'slightly higher', whereas in the calf, sheep, cat and rabbit several arteries originating from neighbouring vessels were seen to enter the carotid body. Occasionally, a larger artery from the carotid bifurcation proceeded towards the carotid body in the rabbit and cat. The vessels entered the hilum of the carotid body and eventually formed a capillary network. Drainage took place by way of a venous plexus and larger collecting veins. Goormaghtigh & Pannier (1939) stated that the carotid body of the cat was supplied by three or four arteries arising from the region of the carotid bifurcation. According to Davis & Story (1943), the carotid body of the cat lies at the base of the ascending pharyngeal artery and receives its blood supply from a branch of the vessel from which the occipital and pharyngeal arteries arise. The blood from the carotid body comes from capillary bundles, enters a number of freely anastomosing veins which form a plexus surrounding the surface of the carotid body, and eventually reaches larger veins in the neck (Schaper, 1892; Sunder-Plassmann, 1930).

In the dog, Winder (1933) found the blood supply of the carotid body 'distressingly variable and involving many fine vessels'. A few dissections disclosed small arteries running through the carotid body region from the occipital artery and sending branches into muscles which were also richly supplied by the vertebral artery; neither a detailed description nor illustrations were given. Comroe & Schmidt (1938) stated that the carotid body of the dog received its blood supply from a small artery arising from the proximal part

of the occipital or the external carotid arteries. This small artery often continued to supply other tissues in the neck, anastomosing freely with branches of the pharyngeal and vertebral arteries. They believed that the artery served both as afferent and efferent vessels to the carotid body, because Addison & Comroe (1937) had seen that the artery supplying the carotid body lost most of its muscular coat and assumed a 'vein-like' appearance near the carotid body attachment. They did not observe any venous channels leading from the carotid body.

The techniques used for the study of chemoreceptor function of the carotid body frequently consist of attempts to isolate the area from the rest of the organism and subject the carotid body to perfusion. It is obvious that the success of these procedures ultimately depends on precise knowledge of the vascular arrangements of the carotid body region.

We have accordingly investigated the arterial blood supply and the venous drainage of the carotid body in those species commonly used in the study of chemoreceptor function: the cat, dog and rabbit.

METHODS

Dogs were anaesthetized with chloralose (0·09–0·1 g/kg body weight, intravenously) or sodium pentobarbitone (nembutal) (40 mg/kg, intraperitoneally) and cats with chloralose (0·08 g/kg, intravenously) after induction with ether. Rabbits received urethane intravenously (1·5 g/kg).

Hycar latex injections. The arterial systems of the animals were injected with hycar latex (British Geon Ltd.). The method used has been described in a previous publication (Chungcharoen, Daly, Neil & Schweitzer, 1952) and is based on the technique employed by Trueta, Barclay, Daniel, Franklin & Prichard (1947) for neoprene latex injections, but modified according to Andrews, Maegraith & Wenyon (1949). The latex was injected at pressures varying from 150 to 220 mm Hg. The preparations were fixed in 10% formol-saline for 7 days before dissection.

Indian ink injections. Indian ink ('Kandahar', George Rowney and Co. Ltd.), to which was added thrombin (Sharpe & Dohme) (100 units/20 ml. indian ink), was injected into the common carotid arteries well below the bifurcation of the common carotid at a pressure of 120 mm Hg. Occasionally, one common carotid was injected at that pressure, while 200 mm Hg pressure was used for the subsequent injection of the opposite common carotid artery. After ligaturing the arteries above the point of cannulation and removal of the cannulae, the preparations were fixed in 10% formol-saline for 7 days before dissection.

When indian ink was injected through the common carotid arteries at a pressure of 120 mm Hg, it was found that it passed through the carotid body into the venous plexus surrounding it. This did not occur with hycar latex, unless the injection pressure was greater than 200 mm Hg (*circa*). This difference is probably due to the greater viscosity of the latex. However, this method of demonstrating the venous drainage of the carotid body was found to be better than injecting the material through the venous side of the circulation. The presence of valves in the veins makes it impossible to inject the carotid sinus region through a cannula inserted into the right auricle, and attempts made to inject the latex through the longitudinal venous sinus of the cat were not entirely satisfactory.

Particular care was taken to avoid any operative interference with the structures of the neck at the level of the common carotid bifurcation. All dissections were made with the aid of a dissecting microscope (magnification up to 50 times). Scale drawings were made at each stage of the dissection.

RESULTS

Carotid body blood supply in the cat

In seven out of eight specimens the carotid bodies were situated on the common trunk from which the occipital and ascending pharyngeal arteries originated; they were placed either close to the external carotid or the ascending pharyngeal artery (Fig. 1). In the remaining animal the carotid body of the right side was found on the proximal portion of the occipital artery, while on the left side it was attached to the occipito-ascending pharyngeal trunk.

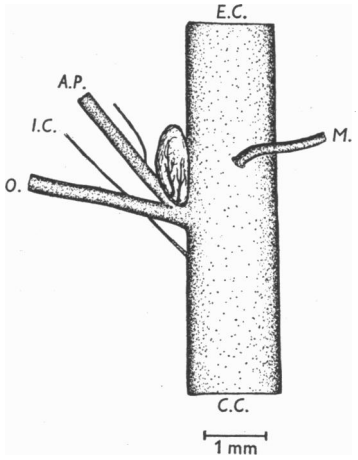

Fig. 1. Ventro-medial view of the left carotid of a cat injected with latex. The carotid body is situated on the occipito-ascending pharyngeal trunk, close to the external carotid. Two small arteries from the occipito-pharyngeal trunk enter the carotid body. In this and subsequent figures: *C.C.* = common carotid artery, *I.C.* = internal carotid artery; *E.C.* = external carotid artery; *O.* = occipital artery; *A.P.* = ascending pharyngeal artery; *M.* = muscular branch. *I.J.* = internal jugular vein; *T.P.P.* = transverse posterior pharyngeal vein; *P.P.* = posterior pharyngeal vein; *L.V.* = laryngeal vein.

The carotid bodies were supplied by two branches coming from the artery to which they were attached, i.e. the occipito-ascending pharyngeal trunk or the occipital artery. In the latter case, one of the two arteries supplying the carotid body continued on its course and entered the superior cervical and the nodose ganglia. In all cases the carotid bodies were well separated from the remnants of the internal carotid arteries which did not participate in their blood supply.

The arteries entered the carotid bodies through the surface which was in contact with the parent vessel. In some cases the arteries continued to supply muscles in the vicinity.

A fine venous plexus originating from the carotid body was observed on its outer surface. This venous network drained into three or four larger veins

(Fig. 2). Usually, these veins ran anteriorly to join the external and internal jugular veins. In one case two of the veins collecting blood from the superficial plexus at the carotid body surface joined directly the internal jugular vein (Fig. 3), while a third vein, arising from the upper pole of the carotid body, ended in the transverse posterior pharyngeal vein. In the specimen illustrated in Fig. 3, the internal carotid artery was well filled throughout its course with

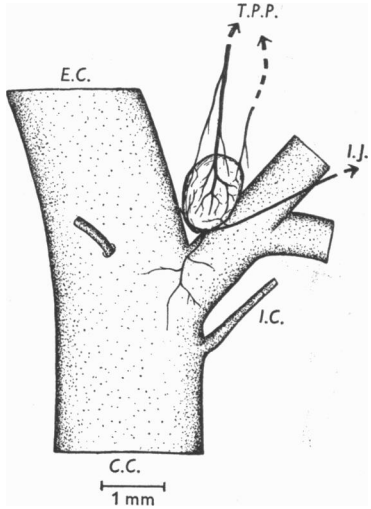

Fig. 2.

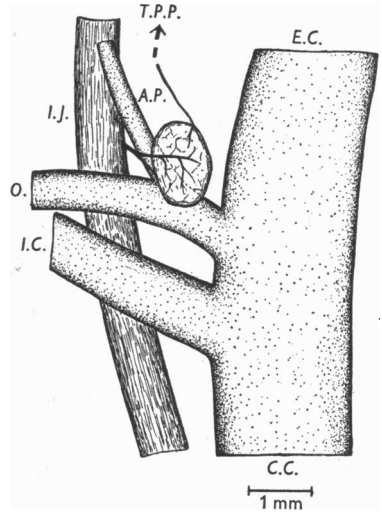

Fig. 3.

Fig. 2. Ventro-medial view of the right carotid of a cat injected with indian ink. The carotid body is situated on the occipito-ascending pharyngeal trunk. A fine venous plexus is seen on its surface and two larger veins drain that area into the internal jugular and the transverse posterior pharyngeal veins. A vein from a neighbouring area also joins that from the carotid body.

Fig. 3. Ventro-medial view of the left carotid of a cat injected with latex. The carotid body is attached to the occipito-ascending pharyngeal trunk and the proximal part of the ascending pharyngeal artery. Two small veins draining the carotid body join the internal jugular vein directly; another vein from the upper pole of the carotid body courses anteriorly to join the transverse posterior pharyngeal vein. In this preparation the internal carotid contained the latex throughout its course.

hycar latex and could be easily followed to the circle of Willis. This was the only specimen showing a well-defined internal carotid artery. The veins draining the carotid body were frequently in communication with small veins coming from the vicinity, particularly from the muscles of the floor of the mouth, the lateral wall of the neck and the pharynx, and the superior cervical and nodose ganglia.

Carotid body blood supply in the dog

In ten out of twelve specimens from adult dogs, the carotid body was found astride the proximal part of the occipital artery (Fig. 4). In one of these

preparations the occipital artery originated from the external carotid a few millimetres away from the carotid bifurcation (Fig. 6). In two other specimens the carotid bodies were situated on the ascending pharyngeal arteries which arose from the external carotids at the same level as the occipital arteries (Figs. 7–9). In one further preparation, a 6-week-old dog, the carotid body was attached to the occipital artery, close to the external carotid.

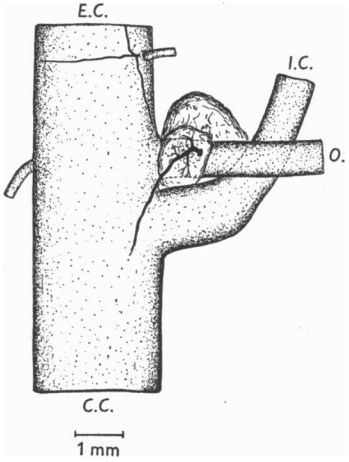

Fig. 4.

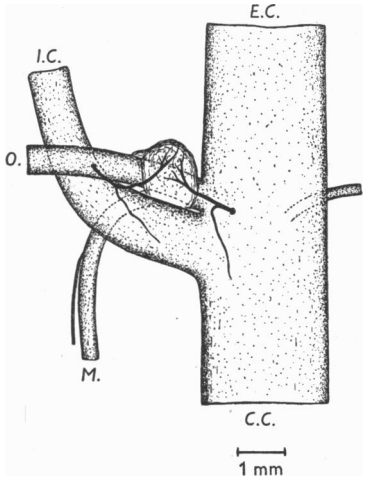

Fig. 5.

Fig. 4. Dorso-lateral view of the left carotid of a dog injected with latex. The carotid body lies astride the proximal part of the occipital artery. An artery, originating from the occipital under the cover of the carotid body, supplies it and the neighbouring area.

Fig. 5. Dorso-lateral view of the right carotid of the same animal as Fig. 4. The carotid body is situated on the proximal part of the occipital artery. It is supplied by two small arteries, one from the external carotid and the other from the occipital artery; they also supply the carotid sinus region. Note that the vessels supplying the carotid body arise from their respective arteries some distance away from it.

The carotid body was supplied by three or four arteries which usually originated from the artery to which the carotid body was attached. In one instance, two branches arose from the external carotid and the occipital artery a short distance away from its point of attachment (Fig. 5). In the specimen illustrated in Fig. 7 the carotid body was situated between two branches of the ascending pharyngeal artery and received its blood supply from both these arteries. Fig. 9 shows a preparation where the carotid body surrounded the proximal part of the ascending pharyngeal artery which arose from the external carotid just above the origin of the occipital artery; one small artery supplying the carotid body came from a muscular branch of the external carotid, and two more vessels originated from the ascending pharyngeal. Some of the arteries serving the carotid body, in addition to sending fine

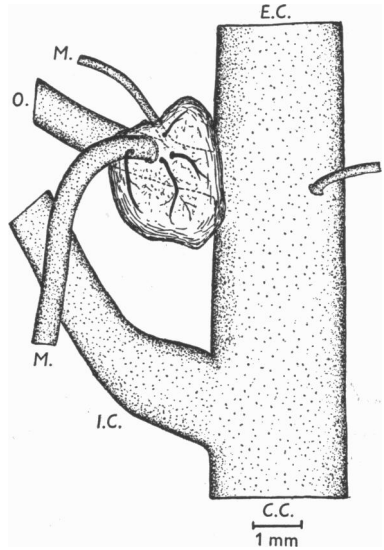

Fig. 6. Ventro-medial view of the left carotid of a dog injected with latex. The carotid body surrounds the proximal part of the occipital artery which originates from the external carotid a few millimetres above the internal carotid. It is supplied by four arteries, two from the occipital artery and two from muscular branches.

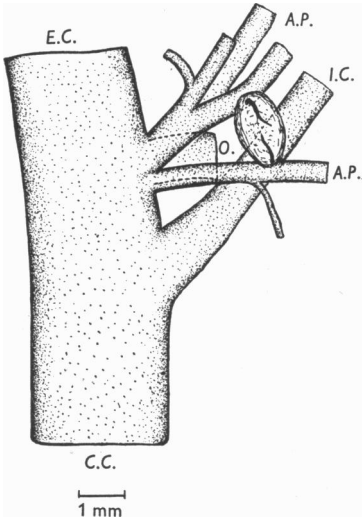

Fig. 7.

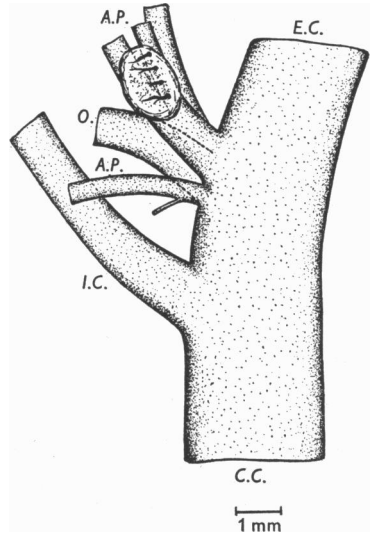

Fig. 8.

Fig. 7. Ventro-medial view of the right carotid of a dog injected with latex. The ascending pharyngeal artery is well developed and arises from the external carotid at the same level as the occipital. The carotid body lies between two branches of the ascending pharyngeal. It receives two arteries, one from each branch.

Fig. 8. Ventro-medial view of the left carotid of the same dog as in Fig. 7. The carotid body is attached to the ascending pharyngeal artery. Four small branches from this artery supply the carotid body. Note the difference in the arrangements of the arterial blood supply of the carotid body on the two sides of the same animal (Figs. 7 and 8).

branches into the region of the carotid sinus (Fig. 5), proceeded to supply adjacent structures.

Thus, the arterial vascular pattern of the dog, while revealing its close relationship mainly to the ascending pharyngeal and occipital arteries, showed considerable variability even in the same animal on comparison of both sides. This inconstancy is probably related to the varied arrangements of the parent

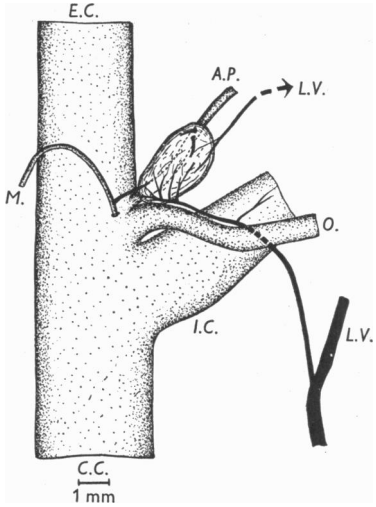

Fig. 9.

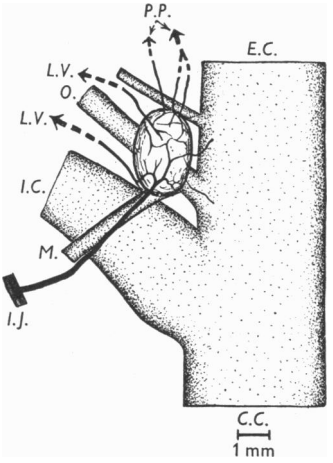

Fig. 10.

Fig. 9. Ventro-medial view of the right carotid of a dog injected with latex. The carotid body surrounds the proximal part of the ascending pharyngeal artery which arises just above the occipital artery. Three arteries supplying the carotid body are shown, one from the muscular branch of the external carotid and the other two from the ascending pharyngeal. Several fine veins are seen leading from the surface of the carotid body to the laryngeal vein, which finally joins the external jugular vein. In this case the internal jugular vein was absent.

Fig. 10. Ventro-medial view of the left carotid of a dog injected with indian ink. The carotid body is situated on the occipital artery. A fine venous plexus on the surface of the carotid body communicates with numerous small veins. The largest vein joins the internal jugular, while the smaller veins join the laryngeal and the posterior pharyngeal which connect with the external jugular vein.

vessels arising from the carotid bifurcation zone. The plexus of small veins arising from the carotid body and lying on its surface closely resembled that in the cat. Several small veins collected blood from this plexus, some of them joining to form larger veins (Figs. 9, 10). Most of the drainage occurred into the internal jugular vein, although small veins often connected with the posterior pharyngeal and the laryngeal veins and thus with the external jugular vein. In the specimen illustrated in Fig. 9, the internal jugular vein was absent and drainage occurred solely via the laryngeal into the external jugular vein.

Carotid body blood supply in the rabbit

In five out of eight specimens the carotid body was found on the dorso-medial aspect of the internal carotid artery (Fig. 11). In three specimens the carotid body adhered to muscle branches of the external carotid in close proximity to the internal carotid (Figs. 12, 13).

The blood supply of the carotid bodies came from one or two small arteries which had their origin from the external carotid (Fig. 11), the internal carotid, or the carotid bifurcation area. The specimen illustrated in Fig. 12 shows two small branches running into the carotid body which originated from a muscular branch of the carotid bifurcation. This illustration also shows a small nutrient vessel leaving this muscular branch at its origin and disappearing in the muscular coat of the carotid sinus region. Very commonly, the vessels continued on their course after sending branches into the carotid body and supplied the superior cervical and nodose ganglia.

The blood from the venous plexus on the surface of the carotid body drained into two or more larger veins which eventually joined the internal jugular vein (Figs. 13, 14). No connexions with the external jugular venous system were found.

DISCUSSION

The observations presented show a somewhat bewildering variability of the arterial blood supply and venous drainage of the carotid body in different species. Considerable variations were also found in animals of the same species and even from side to side in the same animal. This lack of uniformity of the vascular pattern seems to be related mainly to the degree of variation in the arrangements of the common carotid bifurcation, as the carotid body draws its blood from arteries originating from this area.

The situation appears simplest in the cat where the arterial supply leaves mainly from the occipital artery or the occipito-ascending pharyngeal trunk; venous drainage occurs directly into the internal jugular vein or via the transverse posterior pharyngeal vein and its communicating system into the external and internal jugular veins.

In the rabbit, branches from the external or internal carotid arteries, or from the carotid bifurcation supply the carotid body, while the veins drain into the internal jugular system. The rabbit was the only species examined where the internal carotid occasionally contributed to the carotid body blood supply.

It is in the dog that the greatest variability in the vascular arrangements of the carotid body was found. The vessels originated from the occipital and external carotid, from the ascending pharyngeal, or from the ascending pharyngeal artery and a muscle branch of the external carotid. The veins

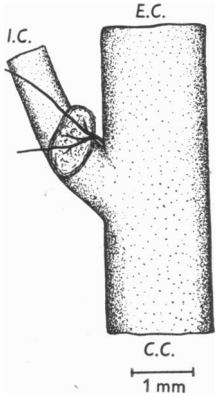

Fig. 11.

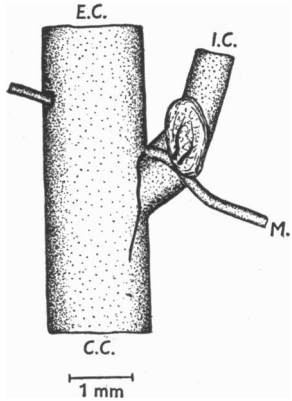

Fig. 12.

Fig. 11. Ventro-medial view of the left carotid of a rabbit injected with latex. The carotid body is situated on the internal carotid artery. It is supplied by an artery arising from the external carotid just above the internal carotid artery. This vessel, having supplied branches to the carotid body, proceeds to supply the superior cervical and nodose ganglia.

Fig. 12. Ventro-medial view of the right carotid of the same animal as in Fig. 11. The carotid body lies on a muscular branch arising from the carotid bifurcation. It is supplied by two branches from that muscular artery.

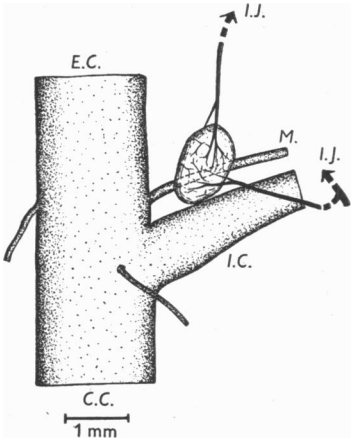

Fig. 13.

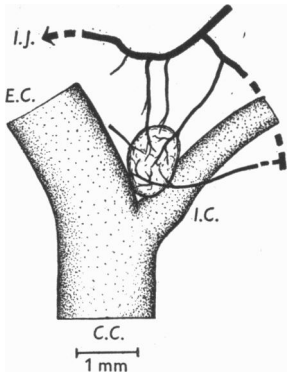

Fig. 14.

Fig. 13. Ventro-medial view of the right carotid of a rabbit injected with latex. The carotid body surrounds the proximal part of a muscular branch which arises from the external carotid above the carotid bifurcation. Two large veins are seen draining the carotid body; they finally join the internal jugular vein.

Fig. 14. Ventro-medial view of the right carotid of a rabbit injected with indian ink. The carotid body is situated on the proximal part of the internal carotid artery. A fine venous plexus is seen on the surface of the carotid body together with several small veins which finally drain into the internal jugular vein.

from the carotid body joined the internal jugular, or sometimes the external jugular when the internal jugular vein was absent; in the former case smaller branches also joined the external jugular vein.

Frequently, the branches of the ascending pharyngeal and occipital arteries which supplied the carotid body continued on their course to supply the superior cervical and nodose ganglia. It is of interest that Patterson (1950), in his studies of the arterial blood supply of the superior cervical ganglion in newborn infants, reported that it derived its blood supply most commonly from the ascending pharyngeal, the superior and inferior thyroid, and less usually from the occipital arteries; the ascending pharyngeal artery was the principal and only constant source. It will be noted that, in man, these vessels originate from the external carotid in the vicinity of the carotid bifurcation.

The anatomical observations presented in this paper explain some of the hazards of the classical carotid sinus—carotid body perfusion experiments. One of the purposes of such experimentation is to study, usually in dogs, reflex responses elicited from carotid body chemoreceptor stimulation by various agents under conditions which rigidly exclude the possibility of such agents having direct access to the medullary centres. However, experiments of this kind frequently fail, either because no chemoreceptor responses can be obtained, or because the preparation is not satisfactorily isolated from the general circulation.

The connexions of branches of the carotid bifurcation area with the cerebral vascular system have recently been demonstrated by Jewell (1952) and by Chungcharoen *et al.* (1952). If these vessels are left open in attempts to isolate the carotid body from the general circulation, the experiment is vitiated because of the ample channels of communication between this region and the brain.

Our observations make it clear that at least some of the experimental failures of carotid sinus—carotid body perfusions are due to the rigid application of a standard technique of dissection to a 'distressingly variable' (Winder, 1933) anatomical situation. If all arteries issuing from the carotid bifurcation area are ligatured too close to the carotid body, there is the danger of tying off also the branches supplying it; in that case, the preparation will obviously be unresponsive.

Moreover, if during dissection the venous drainage is destroyed, a hazard not easy to avoid in view of the intimate relationship of the veins with some of the arteries arising from the carotid bifurcation, then again it is probable that the activity of the chemoreceptor elements would rapidly fail through prolonged congestion. Furthermore, it is unlikely that any injected material will reach the receptors under these conditions. On the other hand, if the venous drainage system is left open, then the preparation will not be isolated from the systemic circulation, and perfusate as well as added materials are

bound to enter the general circulation. In this connexion it may be recalled that some authors have actually denied the existence of a venous system coming from the carotid body (Addison & Comroe, 1937; Comroe & Schmidt, 1938).

On the basis of the anatomical studies presented in this paper, the design of a satisfactory carotid sinus—carotid body perfusion technique must be difficult and complex, if at the same time complete isolation from the general circulation and normally functioning chemoreceptors are desired. Owing to the variation, both in the blood supply to and venous drainage from the carotid body, it is not possible to lay down any fixed procedure for setting up such a preparation. One will have to be guided by the anatomical arrangements which present themselves as to the best means of fulfilling the criteria pertaining to such preparations.

SUMMARY

1. The carotid body blood supply in cats, dogs and rabbits was studied by injecting hycar latex or indian ink—thrombin preparations into the vascular system.

2. In the cat, the arterial supply comes from the occipital artery or from the occipito-ascending pharyngeal trunk. The veins drain into either the transverse and thence external and internal jugular veins, or directly into the internal jugular vein.

3. Three main patterns of arterial supply were found in the dog: branches from the occipital and external carotid, from the ascending pharyngeal, or from the ascending pharyngeal artery and a muscle branch of the external carotid. The veins drain into the internal jugular vein, or, in its absence, the external jugular vein.

4. In the rabbit, branches of the external carotid, internal carotid or carotid bifurcation supply the carotid body; the veins join the internal jugular vein.

5. The arteries supplying the carotid body may proceed and send branches into neighbouring tissues, especially the superior cervical and nodose ganglia. The venous system may communicate with channels coming from structures in the neck and pharynx.

6. Attempts to perfuse the carotid body experimentally should be based on the anatomical patterns of its vascular system.

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