CAROTID-OPHTHALMIC ANASTOMOSES*

FREQUENCY OF EXTERNAL CAROTID AND OPHTHALMIC ARTERY ANASTOMOSES

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ANATOMICAL studies in man on the degree of anastomosis existing between the external carotid artery and the ophthalmic arteries are a necessary condition of the rational surgical treatment of carotid-cavernous fistulae, as this treatment may carry with it a threat to vision in the eye on the operated side if the anastomosis is inadequate. What must be proved is the negative proposition that inadequate anastomosis is rare. Previous anatomical studies do not enable the risk to be accurately assessed, as the number of subjects studied has been too small. Thus the evidence based on perfusion experiments described in the literature does not permit one to state that adequate anastomosis is to be expected in more than 62 per cent. of the population (Elschnig, 1893; Garwood, 1936; Walsh and King, 1942).

The present study was planned with two objects in view. First, it was necessary to choose methods of testing that adequate anastomosis existed, though the use of autopsy material limited the choice to perfusion with water, air, and blood. The use of dyes or neoprene casts was ruled out, and perfusions with blood had to be brief. However, it was possible to test the anastomosis satisfactorily, by demonstrating that a copious back-perfusion occurred within specified conditions of time and perfusion pressure. Secondly, it was necessary to demonstrate that this copious anastomosis existed in all or nearly all of as large a series of perfusions as possible. Only in this way can the frequency of anastomosis be accurately assessed.

From an analysis of the results obtained (Tables I, II, and III) it is concluded that the occlusion of the ophthalmic artery central to the point of origin of its central retinal branch is unlikely to deprive the retina of an adequate anastomotic blood supply. A review of the literature concerning the effects of operations involving ligation of the internal carotid artery points to a similar conclusion. It would not seem that the contralateral anastomosis is always as extensive.

Materials and Methods

Owing to the fact that autopsy material was used, no medium which would stain the face of the subject or occlude its vessels could be injected. Dissection

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of the carotid sheath was mainly digital. The internal carotid and superior thyroid arteries were ligated bilaterally in the neck. The brain was always removed before the experiment, and, after removal of the pituitary gland, the roof of the optic canal was nibbled away with rongeurs. Approximately 10 mm. of the optic nerve were removed, and the ophthalmic artery was made clearly visible and cut free from the internal carotid.

In the first group of thirteen subjects, water and air were injected, with a 50-ml. syringe, into the common carotid artery. The anastomoses were judged to be patent and ample when the fluid was seen to flow from the cut end of the ophthalmic artery within 80 seconds at an approximate pressure of 70-90 mm. Hg, and when, on injection of air, the solid column of perfusion fluid became interrupted, fluid and air bubbles passing in sequence along the lumen of the vessel.

In the second group of nine subjects, the injection medium was citrated blood. It was introduced by injection with a 150-ml. metal syringe, a "Y" tube, and two glass cannulae, which were inserted one into each common carotid artery.

In the third group of eight subjects, water and blood were injected alternately under manometric control. The pressure was maintained with a sphygmomanometer bulb and a 2-l. air reservoir helped to reduce oscillation in the mercury column of the manometer. Since blood is a viscous material, it was thought necessary to determine the actual pressures built up at the cannulae, as opposed to the pressures recorded on the reservoir manometer, and to recalibrate that manometer accordingly. It was found that there was a time lag of approximately 30 seconds between a rise in pressure in the manometer attached to the reservoir and the subsequent rise in that attached to a side-arm of one of the cannulae. The average drop in pressure between the reservoir manometer and the cannula manometer during reading, where the pressure was maintained between 80 and 160 mm. Hg, was 12 mm. Hg.

Observations

Table I represents the incidence of patent anastomoses demonstrated between the ophthalmic artery and the external carotid artery of the same side.

TABLE I
INCIDENCE OF PATENT IPSILATERAL ANASTOMOSES

Group	Perfusion Medium	No. of Subjects	No. of Injections	Anastomoses	
				No.	Per cent.
I	Water and Air	13	23	19	82.6
II	Blood and Air	9	16	16	100
III	Blood, Air and Water	8	10	10	100
Total		30	49	45	91.8 (mean)

Anastomoses between the external carotid and ophthalmic arteries on the same side were demonstrated in 15 to 30 seconds with water and air, and in 40 to 50 seconds with blood and air, the average pressure in both instances being 90 mm. Hg.

The incidence of patent anastomoses between the external carotid artery

of one side and the ophthalmic artery of the opposite side is shown in Table II.

TABLE II
INCIDENCE OF PATENT CONTRALATERAL ANASTOMOSES

Perfusion Medium	No. of Subjects	No. of Injections	Anastomoses	
			No.	Per cent.
Water and Air ...	22	22	7	31.8

The total number of subjects available for this investigation was reduced to 22, because in eight cases one of the external carotid systems had been severely damaged by other procedures. Subjects with only one external carotid system intact were not suitable, as leakage from the damaged vessels made it impossible to get adequate pressure to demonstrate contralateral anastomoses. These anastomoses were demonstrated with water and air in an average time of 70 seconds at a pressure of 80 mm. Hg.

Comment

The age of the subjects ranged from 20 to 80 years. Arteriosclerotic heart disease, neoplastic disease, diabetes mellitus with severe arteriosclerosis, polyarteritis nodosa, and idiopathic thrombo-cytopaenic purpura were amongst the causes of death, but neither cause of death, age, nor sex seemed to have any bearing on the patency of the anastomoses.

As each subject possesses an external carotid and an ophthalmic artery on each side, two results must be recorded in every case. Thus in this series of thirty cases the total number of anastomoses theoretically available is sixty. Seven of the external carotid arteries had been damaged by other procedures and two subjects had to be abandoned because of early staining of the face; therefore the total number of anastomoses actually available for the experiment was 49. Of these 49 possible ipsilateral anastomoses, 45 were demonstrated to be patent. Failure to demonstrate patent ipsilateral anastomoses occurred only in the first two subjects of the series and there is reason to believe that this failure was due to faulty technique; after the first two subjects had been studied, 45 consecutively successful perfusions were performed. The statistical interpretation of Table I is given in Table III (overleaf).

Discussion

In man it has been shown that connexions between the ophthalmic, lacrimal, and middle meningeal arteries are frequent (Adachi, 1928). Anatomical confirmation of the possibility of retrograde flow through the ophthalmic artery has been described in the literature in twelve cases (Elschnig, 1893; Walsh and King, 1942), the ages ranging from 38 to 77 years.

TABLE III
FREQUENCY OF IPSILATERAL ANASTOMOSES
($P=0.99$)

Data	No. of Perfusions	No. Successful	At least x per cent. of Patent Anastomosis ($P=0.99$) in the Population
Elschnig combined with Walsh and King ...	12	12	62
Author (including first four perfusions)... ..	49	45	76.8
Author (excluding first four perfusions) ...	45	45	89.8
Elschnig, combined with Walsh and King, and Author (corrected)	57	57	91.9

Calculated from the Table of Fiducial Limits of the mean of a Poisson distribution (Garwood, 1936).

Swan and Raaf (1951) described five cases of carotid cavernous fistula which had simultaneous ligation of the internal and external carotid arteries. During the week after the operation, in all cases, there was hypotony, with diminished volume and pulsation of the retinal vascular tree. In three instances a typical retinopathy developed, which in one case lasted for 6 months.

Singleton (1939) quotes an example of carotid-cavernous aneurysm in which backflow in the ophthalmic artery was contributed to by both external carotids, and Denny-Brown (1951), in a case of occlusion of the right internal carotid, demonstrated by arteriography that retrograde flow took place into the intracranial portion of the right internal carotid *via* the right external carotid and ophthalmic arteries. While both Elschnig and Walsh and King, for a few cases, demonstrated in all of them the patency of the anastomosis between the external carotid and contralateral ophthalmic artery, in our series it was proved in only seven of 22 cases. This result and the time and pressure data suggest that the contralateral anastomosis has not the same status as regards extent, or frequency of occurrence, as the ipsilateral anastomosis; indeed, this is in accordance with the greater incidence of trouble, hypotonia, retinitis, etc., following the ligation of the internal and external carotids on the same side (Swan and Raaf, 1951).

If it can be assumed that ipsilateral and contralateral anastomotic channels are present and patent, the question arises whether they will be able to supply the central retinal artery adequately within the survival time of the anoxic retina, upon deliberate occlusion of the ophthalmic artery. While in rats this time has been shown to be 15 minutes (Smith and Baird, 1952), the exact length of time available in man is unknown. Schurr (1951) has shown that these anastomoses do increase in size after relatively less drastic lesions, such as middle cerebral thrombosis. It is suggested, by the good visual results in the cases reported by Swan and Raaf (1951) and by Denny-

Brown (1951), that these anastomoses became available in time. Singleton (1939) quotes a case in which the contralateral external carotid was the main source of supply and in which vision did not deteriorate.

In terms of the test described in this paper the ipsilateral anastomosis may be inadequate in about 10 per cent. of cases. This percentage was calculated from the confidence limits of the mean of a Poisson distribution (Garwood, 1936). It was considered legitimate to use the Table of Limits of the Poisson distribution in the case of the closed ipsilateral anastomoses, as this is a rare occurrence, and in this circumstance a binomial distribution approximates to the Poisson (Table III).

The same conventions cannot be applied to the contralateral data. However, these figures can be treated as a sample of a moderately asymmetrical binomial distribution and confidence limits assigned. If the Tables of Koller (1953) are used, the 99.73 per cent. confidence limits for the observed figure of 31.8 per cent. patent anastomoses in 22 perfusions are found to be 7 and 65 per cent. Thus, there is no ground for confidence that the anastomosis will react positively to this test in more than 7 per cent. of the general population, but it can be stated that not more than 65 per cent. will react positively to this test.

Summary and Conclusions

Patency of the ipsilateral anastomoses between the ophthalmic and external carotid arteries was found in 45 of 49 perfusions (91.8 per cent.) and patent contralateral anastomoses were found in seven of 22 perfusions (31.8 per cent). The method involves injection of air, water, and citrated blood, and observation of the time taken for flow to occur from the ophthalmic arteries. Cause of death or intercurrent illness seems to have no bearing on the results.

It is also suggested, by the clinical evidence reviewed, that ipsilateral anastomoses are functionally adequate to preserve vision in the event of planned occlusion of the ophthalmic artery near its point of origin. If reliance is placed on the contralateral anastomoses alone, the risk of visual loss would seem to be considerably greater.

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