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Clinical Anatomical Study of the Macroscopic Anastomoses of the Ophthalmic Artery in the Periorbital Region

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Summary. Using latex injections we have studied the anastomoses between the ophthalmic artery (a. ophthalmica) and the branches of the external carotid (a. carotis exerna) in the orbital region (regio orbitalis). We have limited this report to the macroscopic anastomoses which have a functional supply and which are accessible to examination by the Doppler technique.

After examination of 60 specimen pairs it is clear that most anastomoses were inconstant. We have thus recorded their frequency: for the facial artery (a. facialis) the frequency of anastomoses was 60%, for the superficial temporal artery (a. temporalis superficialis) it was 33%, for the infraorbital artery (a. infraorbitalis) anastomoses were present in 37%.

We have furthermore studied the association between the different anastomoses to establish whether their relationship to one another was organized or simply random. We found that the anastomoses between the branches of the opthalmic artery and those of the external carotid artery were much more frequent on the right side.

Finally, we have compared our anatomical results with those of a series of Doppler examinations designed to detect reversal of the circulation at the level of different anastomoses of the ophthalmic artery in subjects who presented with unilateral thrombosis of the internal carotid artery (a. carotis interna). This study revealed a good correlation between the anatomical findings and those observed on Doppler examination. There are however differences which can be explained by the small number of subjects examined, by the calibre of the vessels and also by the fact that in certain subjects, the circle of Willis (circulus arteriosus cerebri) was particularly well-developed. In such circumstances the anastomoses were not clinically functional and there was no reversal of blood flow within them.

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Etude anatomo-clinique des anastomoses macroscopiques de l'artère ophtalmique dans la région périorbitaire

Résumé. Après injection au latex, nous avons étudié les anastomoses entre l'artère ophtalmique (a. ophtalmica) et les branches de la carotide externe (a. carotis externa) dans la région orbitaire (regio orbitalis). Nous n'avons retenu que les anastomoses macroscopiques qui peuvent éventuellement jouer un rôle de suppléance et être étudiées par examen Doppler.

Nous avons constaté pour 60 hémifaces que les anastomoses étaient inconstantes. Nous avons donc étudié leur fréquence: pour l'artère faciale (a. facialis) elle est de 60%, pour l'artère temporale superficielle (a. temporalis superficialis) de 33% et pour l'artère infra-orbitaire (a. infraorbitalis) qui donne une anastomose indirecte de 37%.

Nous avons étudié ensuite l'association de ces différentes anastomoses entre elles pour voir s'il existait un balancement dans leur présence ou si leur association était due au hasard. Nous avons constaté en outre que les anastomoses entre les branches de l'artère ophtalmique et les branches de l'artère carotide externe étaient nettement plus fréquentes du côté droit.

Dans un dernier temps, nous avons comparé nos résultats anatomiques avec ceux d'une série d'examens Doppler qui étudiait l'inversion du sens circulatoire au niveau des différentes anastomoses de l'artère ophtalmique chez les sujets qui présentaient une thrombose unilatérale de l'artère carotide interne (a. carotis interna). Nous avons alors constaté qu'il existait une bonne corrélation entre nos résultats anatomiques et ceux observés après cet examen. Il y a

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cependant des différences qui peuvent s'expliquer par le petit nombre des sujets, par le calibre des vaisseaux, et peut-être aussi par le fait que chez certains sujets, le polygone de Willis (circulus arteriosus cerebri) était très important. Dans une telle disposition, les anastomoses ne sont pas utiles cliniquement et il n'y a pas de renversement circulatoire.

Key words: Ophthalmic artery – External carotid artery – Anastomoses – Doppler

Introduction

It is generally held that the territories of the external and internal carotid arteries communicate at the level of the internal angle of the eye by an anastomosis situated within a canal, between the facial artery and the ophthalmic artery. This anastomosis is generally believed to be constant, insofar as such studies have been performed routinely using the Doppler technique in case of cerebrovascular accident. We have therefore performed an anatomical study of this anastomosis and have found that in fact it is inconstant and highly variable. We have furthermore studied the other anastomoses which arise from the external carotid artery by the intermediary of the infraorbital artery and the facial artery. In this case our anatomical studies were limited to anastomoses which were macroscopically visible and accessible to dissection, and which might provide an immediate functional supply in the case of circulatory disturbance.

Secondly we have compared the anatomical results with clinical findings. In those patients presenting with unilateral thrombosis of the internal carotid artery verified by carotid arteriography, we have used the Doppler technique to study the frequency of reversal of the circulation at the level of anastomosis between the ophthalmic artery, the facial artery and the superficial temporal artery.

Materials and Methods

Coloured latex injections into the cranial and cerebral vessels were performed in 30 autopsy subjects aged between 65 and 75 years. The injections were given via the common carotid arteries exposed in the supraclavicular region (regio supraclavicularis); this particular approach also allowed us to check the two vertebral arteries (a. vertebralis) and their origin and to clamp them at the end of the injection to ensure filling of the arterial network. In general, 200 to 300 cm^3 of latex was sufficient.

We subsequently dissected the whole network of vessels of the face, paying particular attention to the visible macroscopic anastomoses (diameter at least 0.5 mm) which link branches of the ophthalmic artery to those of the external carotid artery. In practice we limited our dissection to those anastomoses likely to play an immediate supply role in case of circulatory insufficiency in the internal carotid system and which at the same time were accessible to Doppler examination. The anatomical dissections have allowed us to establish the frequency of the different anastomoses and their arterial dependency, and to gain a general impression of the anastomotic system of the face.

Finally, we compared the anatomical results with those of Doppler examination in subjects affected by stenosis of the internal carotid artery.

Results of the Anatomical Studies

Firstly, we will consider the frequency of anastomoses between the ophthalmic artery and the facial artery for the 60 specimen pairs, and then for the 30 subjects.

Subsequently we will report the frequency of the other anastomoses which link the external carotid artery and the ophthalmic artery in the peri-orbital region (Table 1 and Fig. 1).

Table 1. Frequency of the different types of anastomosis in 60 paired specimens of the face

Artery	Number	Frequency
Ophthalmic artery Facial artery	36	60%
Ophthalmic artery Superficial temporal artery	20	33%
Facial Artery Infraorbital artery	22	37%

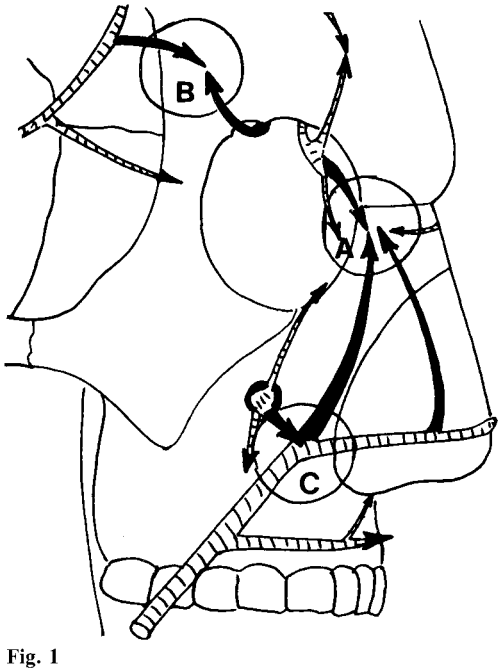

Fig. 1
Principal anastomoses of the ophthalmic artery: *A* facial artery, *B* superficial temporal artery, *C* infraorbital artery

Principales anastomoses de l'artère ophtalmique: *A* artère faciale, *B* artère temporale superficielle, *C* artère infra-orbitaire

Anastomosis Between the Ophthalmic Artery and the Facial Artery

A) In our series of 60 specimen pairs, we found 36 (60%) in which anastomosis was present between the ophthalmic artery and the facial artery at the internal angle of the eye. On analysing the results in more detail, we found that the anastomosis was present on the right side on 21 occasions and on the left side on 15 occasions. Furthermore, it was possible to classify arbitrarily three anatomical types according to the calibre and morphology of the anastomosis.

1) Most commonly (28 cases) the anastomotic artery was classical. It was formed by the union of the nasal artery (a. nasi), branch of the ophthalmic artery and the angular artery (a. angularis), branch of the facial artery; it sometimes passed into the nasogenial groove for a short distance on the external surface of the nose (regio lateralis nasi) and its calibre was around 1 mm.

2) In 3 cases, the anastomosis followed a similar course but was distinguished by a considerably greater calibre, achieving 2 to 3 mm. In one of our subjects, this voluminous anastomosis was present on both sides, presenting a veritable 'rete mirabile'.

3) In the five remaining cases, the calibre was of medium proportions and its arrangement was distinguished by the course of the artery: the anastomotic network was supplied by the dorsal artery of the nose (a. dorsalis nasi) which was an extension of the nasal artery, and provided an arterial network that united the facial arteries of the two sides of the face.

B) In considering the third type mentioned above, it is worth emphasizing the frequency and volume of the anastomoses which unite the two facial arteries. They are formed by arterial arcades of large calibre situated at the point of the nose or in the superior lip. They participate in the anastomosic system concerned with the distribution of the blood between the two sides of the face. On the contrary, anastomoses between the two facial arteries at the base of the nose are rare and are always formed of slender vessels.

C) Finally, there was no direct communication between the ophthalmic artery and the facial artery in the remaining 24 (40%) cases in the series. To be certain of this, it was necessary to perform fairly extensive dissections of the periorbital vessels, in particular at the level of the nose; in practice, a dominant ophthalmic artery may descend as far as the tip of the nose without anastomosing with any other artery, and limited dissection may be deceptive. Furthermore, in one of our cases, there was the typical anastomosis between the facial and the ophthalmic arteries at the internal angle of the eye, but further dissection revealed that there was no true facial artery, but that the anastomosis took its origin from the infraorbital artery.

D) Distribution of anastomoses between the ophthalmic and the facial artery in different subjects: This study was of particular interest because we noted that among the 30 subjects studied, an anastomosis between the ophthalmic and the facial artery occurred bilaterally in 9 of them, unilaterally in 17, and was entirely absent in the remaining 4, whatever the calibre of the vessels.

The External Carotid Artery

The external carotid artery sends anastomoses to the ophthalmic artery by the intermediary of the superficial temporal artery and infraorbital artery; these anastomoses may be isolated or associated with those which arise from the facial artery.

A) The anterior branch of the superficial temporal artery sends an anastomosis to the supraorbital artery (a. supraorbitalis) before ascending into the frontal region (regio frontalis). It is of moderate calibre, around 0.5 mm. The anastomosis was present in 20 (33%) cases in our series. The other branches pass towards the circle of palpebral arteries (arteria palpebrale) and orbital arteries, are of very fine calibre, and are not considered further.

B) The internal maxillary artery achieves an indirect anastomosis via the facial artery.

1) The infraorbital artery, branch of the internal maxillary artery (a. maxillaris interna), frequently gives off a large branch which joins the facial artery or the nasal arcade at the level of the alae nasi. This circle plays a direct role in increasing the flow of blood into this vessel, and may also provide a functional supply when only an anastomosis between the facial artery and the ophthalmic artery exists. Altogether we found: an anastomosis between the infraorbital and the facial artery in 22 (37%) of cases; an anastomosis both between the infraorbital and the facial artery and between the ophthalmic and the facial arteries in 16 of the 22 cases. A direct anastomosis was thus present in 27% of the total.

2) Other types of anastomoses with the infraorbital artery within the orbital region were found, but comprised only fine vessels entering the palpebral network; these vessels arose directly from the infraorbital artery either at the level of the face or at the level of the inferior orbital fissure (fissura orbitalis inferior).

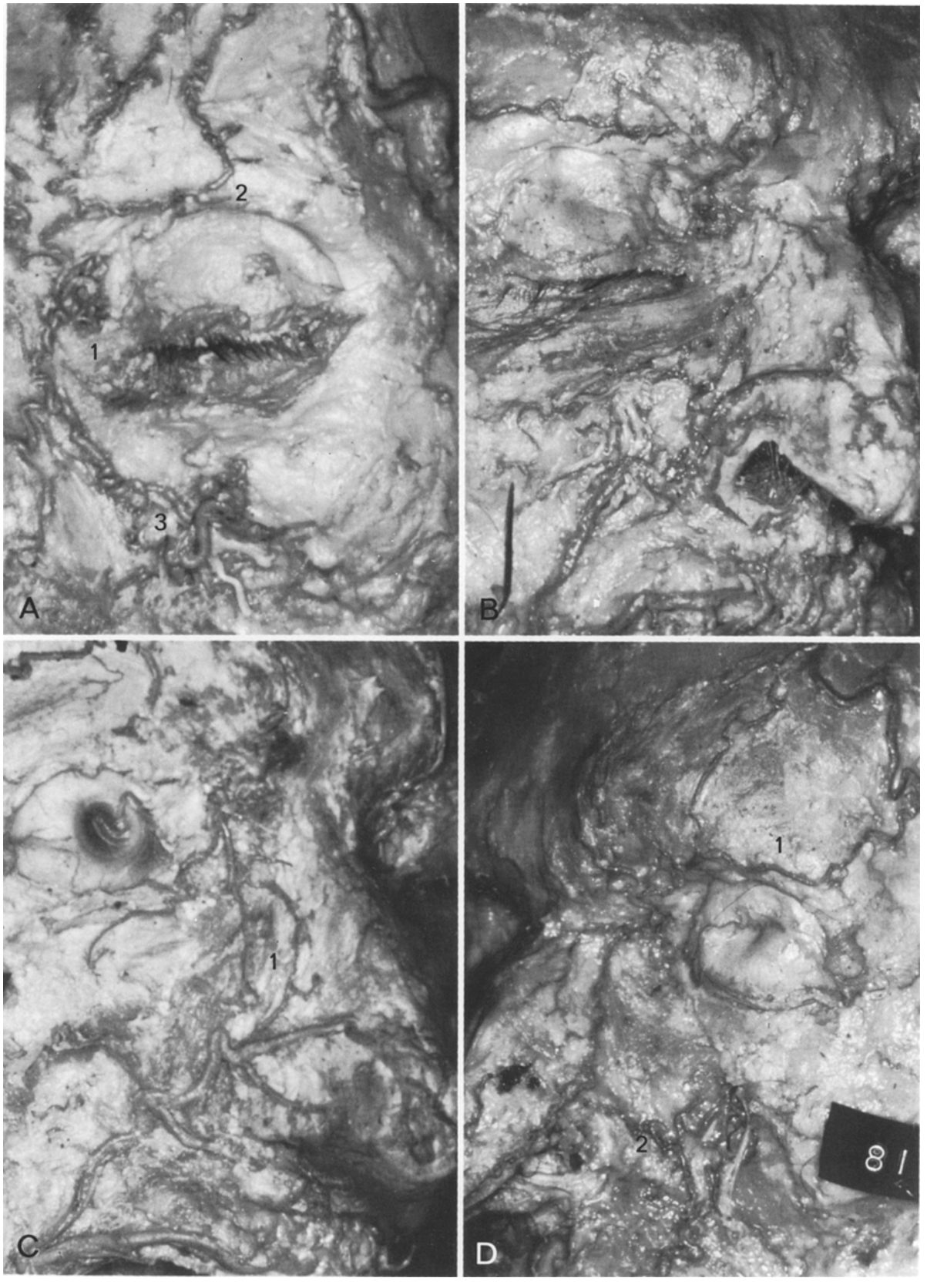
2
1
3
A
B
1
C
1
2
81
D

Table 2. Number of anastomoses associated with the ophthalmic artery in 60 paired specimens of the face

Arteries	Number observed	Theoretical number
Facial artery Superficial temporal artery	13	12
Facial artery Superficial temporal artery Infraorbital artery	7	8.24
Superficial temporal artery Infraorbital artery	8	7.3

Table 3. Comparison between the two sides

Arteries	Right (30)	Left (30)
Facial ophthalmic	21	15
Infraorbital facial	13	7
Superficial temporal ophtalmic	13	9
Total	47 = 52%	31 = 34%

Anatomic Distribution of the Anastomoses

A) Taking into account the above anatomical findings, which were obtained from aged subjects who were generally atheromatous, we have tried to establish whether the association of several anastomoses of the ophthalmic artery from the left side or the right side or in a given subject was random, or whether other factors, in particular circulatory, were responsible. If we start by assuming that the association of the three types of anastomoses on one side of the face or the other is random, it is possible to calculate the theoretical frequency with which they should exist; in practice one may consider the anastomoses as independant variables and in this case, the frequency of association would be equal to the overall product of frequencies. By way of an example, in the case of the anastomosis between the ophthalmic artery and the facial artery, the frequency for the 60 specimen pairs was 60%, that of the anastomosis between the ophthalmic artery and the superficial temporal artery, 33%. In theory therefore, if the association were random, we should find a frequency of association equal to $60\% \times 33\% = 19.8\%$; this means that for 60 pairs, 12 should possess both anastomoses. Basing our analysis on this principle, we have drawn up a table which has allowed us to compare the observed frequencies.

Table 4. Frequency of anastomoses between the facial artery and the ophthalmic artery in 30 subjects

Number of sides showing anastomoses	Theoretical number	Observed number
1	15	17
2	11	9
0	4	3

B) Comparison of the figures given in Table 2 leads to three conclusions:

1) The association of the anastomoses of the ophthalmic with the facial and the superficial arteries is probably random because the numbers are very close.

2) The presence of an anastomosis between the facial and the infraorbital artery does not appear to modify the frequency of the above association.

3) Finally if the same analysis of association between anastomoses of the facial artery and the ophthalmic arteries is made, not on individual specimens but by subject, it is possible to define subjects in whom the anastomosis is unilateral, bilateral or absent. Again, however, we found that the theoretical and observed results were very close (Table 4).

On the whole, the distribution of the different types of anastomoses between the branches of the ophthalmic artery and the external carotid artery seemed to be random, each individual possessing the potential for a variety of anastomoses which was determined at birth. Any functional supply can therefore only come about by an increase in the calibre of arteries in subjects who already have arterial anastomoses.

C) If one compares the number of anastomoses of the branches of the external carotid artery with those of the ophthalmic artery at the level of the face, a difference between the two sides becomes very clear cut. There are 50% more anastomoses on the right than of the left side. It would be interesting to study the impact of these differences on the frequency and

Fig. 2A–D

A The three anastomosis between the ophtalmic artery and the branches of the external carotid artery (*1* facial artery, *2* superficial temporal artery, *3* infraorbital artery). **B** No anastomosis. **C** Anastomosis by the dorsal artery of the nose (*1*). **D** Two anastomosis of the ophtalmic artery with the superficial temporal artery (*1*) and the infraorbital artery (*2*)

A Les trois anastomoses entre l'artère ophtalmique et les branches de l'artère carotide externe (*1* artère faciale, *2* artère temporale superficielle, *3* artère infraorbitaire). **B** Pas d'anastomose. **C** Anastomose par l'artère dorsale du nez (*1*). **D** Deux anastomoses de l'artère ophtalmique avec les artères temporale superficielle (*1*) et infraorbitaire (*2*)

Table 5. Frequency of anastomoses of the ophthalmic artery in the orbital region

Arteries	Anatomical frequency	Doppler frequency
Ophthalmic artery Facial artery	36/60 = 60%	14/29 = 48%
Ophthalmic artery Superficial temporal artery	20/60 = 30%	6/21 = 28%

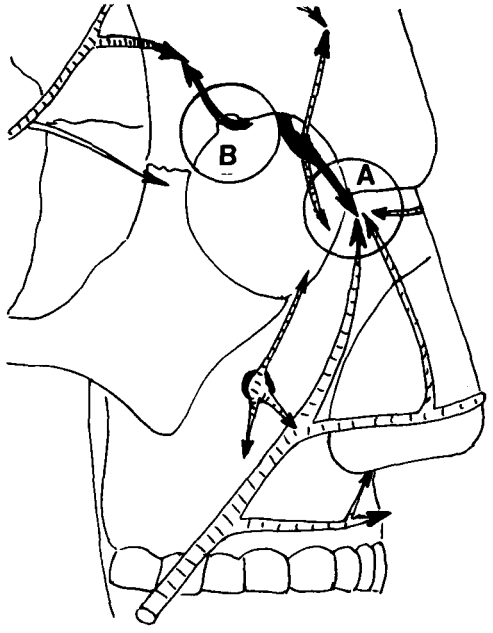

Fig. 3
Anastomoses of the ophthalmic artery: Doppler findings: *A* facial artery, *B* superficial temporal artery

Anastomoses de l'artère ophthalmique étudiées par l'examen Doppler: *A* artère faciale, *B* artère temporale superficielle

severity of neurological problems, particularly ocular problems, arising from thrombosis of the internal carotid artery (Table 3).

Doppler Study of the Anastomoses of the Ophthalmic Artery

A) *Using the Doppler technique we have studied* a series of patients presenting unilateral thrombosis of the internal carotid artery. In order to obtain a homogenous and therefore interpretable group from the hemodynamic point of view, we eliminated from our study those whose Doppler results indicated severe stenosis of the internal carotid artery or stenosis of the common carotid artery. In each individual the patency of the carotid system was checked by carotid angiography. In analysing our results only those cases

Table 6. Frequency of anastomoses of the ophthalmic artery in the orbital region (II). Influence of the circle of Willis

Arteries	Anatomical frequency	Doppler frequency	%Corrected for circle of Willis
Ophthalmic artery Facial artery	60%	48%	+15% = 63%
Ophthalmic artery Superficial temporal artery	33%	28%	+ 8% = 36%

in whom reversal of the direction of circulation within the anastomoses occured were included, contrary to certain reported series which included in the same analysis cases with circulatory reversal as well as others in whom the direction of flow was normal and only the rate of flow diminished.

B) *The Doppler study* was based principally on the anastomoses of the ophthalmic artery with the facial and superficial temporal arteries (Table 5 and Fig. 3).

1) The Doppler study at the internal angle of the eye centered on the anastomoses coming from the facial artery; it was carried out in 29 subjects and we found an inversion of flow in 14 (48%) of cases. Corresponding results from the literature are very variable, ranging from 40% (Orgogozo et al. 1978) to 84% (Müller and Gonzalez 1974; Shoumaker and Bloc 1978). When these results are looked at in more detail it is clear that only the first mentioned is comparable to our own, being concerned solely with a reversal of circulation in the ophthalmic artery; on the other hand the other two studies mixed cases with reversal of flow with those whose flow was in the normal direction but diminished.

2) Doppler studies of the anastomoses between the superficial temporal and ophthalmic arteries have been described by Brockenbrough (1970); he combines the study of the supraorbital artery with the Doppler technique known as transocular.

We believe that these two methods only take account of the anastomoses between the orbital artery, terminal branch of the ophthalmic artery, with a collateral of the anterior branch of the superficial temporal artery. In effect: The Doppler examination was carried out at the level of the supraorbital ridge in the axis of the supraorbital artery.

Secondly, compression of the superficial temporal artery led to modifications in flow registered by the Doppler in the supraorbital artery; in particular in certain selected cases it was possible to restore the normal direction of flow which was otherwise reversed by compressing the superficial temporal artery; we were able to do this in many of our cases.

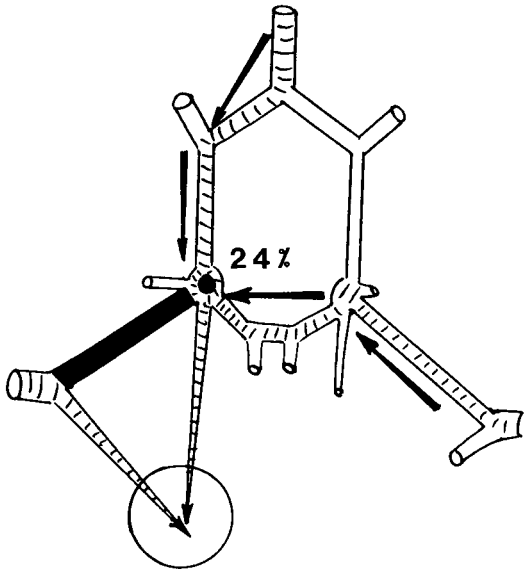

Fig. 4
Supply to the circle of Willis: 24% (after Gouazé)

Suppléance dans le polygone de Willis: 24% (d'après Gouaze)

We studied 21 patients. We found a reversed flow in 6 of them (28%); we have been unable to find a comparable study in the literature.

The study of flow reversal is even more important in subjects who present with thrombosis of the internal carotid artery, some of whom will benefit from a temperosylvian anastomosis. It is therefore better to avoid using the anterior branch for surgical anastomoses.

Comparison Between Anatomical Findings and Results of the Doppler Study

A comparison of our two series of results show considerable analogy between the anatomical and Doppler studies. However if one accepts the hypotheses that reversal of flow detectable by Doppler is only likely to occur in the presence of direct macroscopic anastomoses, the frequency of reversal of flow using this technique was lower than might be suggested by anatomical methods. This difference may be explained in several ways: a) we were able to study anatomically vessels which were otherwise too small to be picked up using the Doppler technique. b) some of our patients perhaps possessed a hyperfunctional circle of Willis (Table 3 and Fig. 4).

If we consider this third hypothesis, a highly functional circle of Willis might avoid the need for circulatory reversal in the anastomoses of the ophthalmic artery, even in the case of internal carotid thrombosis, the build up in pressure at the termination of the internal carotid being sufficient. We have attempted to establish the percentage of cases in whom the termination of the internal carotid recived major anastomoses from the contralateral carotid or from the vertebrobasilar system. However, there were insufficient numbers in our series to make a valid assessment of frequency and we refer the reader to the work carried out by Lazorthes et al. (1979) on 200 circles of Willis, where the percentage of cases in which the terminal part of the internal carotid received major anastomoses from the contralateral carotid or vertebrobasilar system was in the order of 24%.

If the results of our Doppler study are corrected on the basis of this 24%, our two series of results become virtually identical; Lye et al. (1976) reported 22% of false negatives, a finding in favour of our hypothesis. However, despite all the small number of cases which we were able to study by the Doppler and anatomical methods remains insufficient to make any firm deductions.

Conclusion

In conclusion we have found: that the macroscopic anastomoses between the ophthalmic and external carotid artery at the level of the face are inconstant and that they are more frequent on the right side.

In our series of patients with an internal carotid thrombosis at the neck, a good correlation exists between the anatomical frequency of these anastomoses and the frequency of reversal of flow based on Doppler findings.

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