Carotid-ophthalmic aneurysms

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SYNOPSIS Thirty-two cases of carotid-ophthalmic aneurysms are reviewed. As with intracranial aneurysms in other positions they present mainly with subarachnoid haemorrhage but, in spite of their close proximity to the optic nerve, visual involvement is infrequent. They are more common in women, more frequent on the left side, and more prone to multiplicity. In cases of multiple aneurysms a carotid-ophthalmic aneurysm is usually an incidental finding. Detailed angiographic studies employing various projections are required before treatment can be planned. Yet angiography does not always disclose some of the technical difficulties that may be encountered during surgery. Different methods of treating these aneurysms are discussed and suggestions for safe direct surgery made.

Aneurysms arising from the internal carotid artery in the region of the origin of the ophthalmic artery, though infrequent, are no less important than any other intracranial aneurysm. However, very little had been written about them until Drake *et al.* published their article in 1968. As they are in close relation with the optic nerve, cavernous sinus, and carotid siphon these aneurysms present special problems during diagnosis and direct surgical treatment. However, in the last decade significant progress has been made in the knowledge and management of intracranial aneurysms. Progress in neuroradiology and anaesthesia as well as the introduction of the operating microscope and other technical aids in neurosurgery have enabled surgeons to manage these aneurysms with more confidence, rather than depending entirely on the time-honoured method of cervical carotid ligation.

Carotid-ophthalmic aneurysms are comparatively rare; Locksley (1966) in a report on the Co-operative Aneurysm Study found a total figure of 143 in 2672 demonstrated intracranial aneurysms. Bull (1962) in a study of 1769 intracranial aneurysms did not analyse carotid-ophthalmic aneurysms separately but grouped them with other aneurysms arising from the cerebral portion of the internal carotid artery. In

the present study from 1958 to 1972, carotid-ophthalmic aneurysms were demonstrated at carotid angiography in 32 cases from a total of 1245 cases showing single or multiple aneurysms. There was a marked preponderance of females over males in this group, 81% being females. Seventy-two per cent of the cases were in the age group between 36-55 years (Table 1). There was none below the age of 18 and only two above the age of 60 years.

TABLE 1
AGE INCIDENCE

Age (yr)	No.	Percent
18-25	2	6.2
26-35	3	9.3
36-45	10	31.4
46-55	13	40.7
56-62	4	12.4

SYMPTOMATOLOGY

Twenty-seven cases in this series presented with proven subarachnoid haemorrhage (Table 2). In one case (case 16) subarachnoid haemorrhage was presumed from the presentation and appearances at angiography but was not confirmed by lumbar

TABLE 2
PRESENTING SYMPTOMS

	Total	Cases with		
		Carotid- ophthalmic aneurysm alone	Multiple aneurysms	Carotid- ophthalmic aneurysm responsible
SAH	23	14	9	15
SAH with visual symptoms	4	4	0	4
Visual symptoms only	4	3	1	4
Recurrent hemiplegia	1	1	0	1

SAH: subarachnoid haemorrhage.

puncture. Eight cases presented with some form of visual disturbance but four with progressive optic atrophy had not suffered a subarachnoid haemorrhage (cases 1, 5, 12, 25). It is interesting to note that some patients with visual symptoms had been seen in a number of clinics before they presented to a neurosurgeon because of either subarachnoid haemorrhage or impending blindness. In this respect case 25 is instructive.

CASE 25 This 50 year old lady was referred to an eye clinic on 16 October 1970 with sudden deterioration of vision in the left eye. She also complained of severe headache and pain behind the same eye. For the past seven years she had been complaining of

FIG. 1 Case 25. Large left carotid-ophthalmic aneurysm in midline suprasellar position. The neck of the sac is dilated and extends through the dural opening. (a) Lateral projection. (b) Half-axial oblique projection. (c) Right carotid compression, showing good cross-flow and elevation of the anterior part of the circle of Willis.

almost disappeared. Vision in the right eye had improved remarkably from 2/60 to 6/5 (Fig. 2) with recovery of the scotoma.

Accurate and detailed angiography employing numerous projections is essential in the investigation of carotid-ophthalmic aneurysms, as the decision on the surgical management of each individual case may depend upon the anatomical findings at angiography. The relationship of the aneurysm to the anterior clinoid process and the configuration of the neck of the sac are especially important factors.

For classification of the angiographic appearances (Table 3), the sizes of the carotid-ophthalmic aneurysms in this series were divided into three categories: small—seven cases (less than 25 mm² on the film), medium—nine cases (between 25 and

FIG. 3 Case 5. Bilateral carotid-ophthalmic aneurysms. (a) Large right aneurysm with fundus in suprasellar position. (b) Film of same aneurysm two seconds after injection showing retention of contrast medium. (c) Small left carotid-ophthalmic aneurysm. (d) Right carotid compression showing good cross-flow and elevation of anterior part of circle of Willis by the large suprasellar aneurysm.

TABLE 3

ANGIOGRAPHIC APPEARANCE (33 ANEURYSMS)

Size	
Small (less than 25 mm ²)	7
Medium (25–60 mm ²)	9
Large (greater than 60 mm ²)	17
Shape	
Bilocular	8
Unilocular	25
Retention of contrast medium indicating turbulence	
Positive	6
Negative	27
Further analysis of larger aneurysms (26 aneurysms)	
Relation to anterior clinoid process	
Medial	22
Lateral	4
Direction of sac	
Upward	10
Backward	14
Forward	2
Position of tip of fundus of large aneurysms	
Above diaphragma sellae	11
Above tuberculum sellae	5

60 mm²), and large—17 cases (greater than 60 mm²). The measurements of area were made on the lateral projections of the aneurysms in all the cases, as these were exactly comparable and gave an adequate assessment of size.

The fundus of the sac as it enlarges upwards may pass medial or lateral to the anterior clinoid process. Of the 26 aneurysms large enough to reach up to the anterior clinoid process, 22 were directed medial to the process and four lateral to the process (cases 3, 11, 17, and 19). It is important to make this distinction angiographically before operation as the surgical technique is more difficult if the sac lies medial to the anterior clinoid process. Most commonly the proximal part of the sac is directed upwards, and in the larger aneurysms in this series the distal part of the sac was directed backwards in 14 cases and directly upwards in 10 cases. In only two cases was the fundus of the sac directed forwards. The direction of the sac and the position of the tip of the fundus of each aneurysm are analysed in detail in Tables 7, 8, and 9, and the anatomical position of the fundus is summarized in Table 4. In the larger aneurysms the fundus lay above the diaphragma sellae in 11 cases and above the tuberculum sellae in five cases, causing a space-occupying effect in the suprasellar region and usually elevating the anterior cerebral artery in the circle of Willis on one or both sides (Figs 1 and 3). Thus, in these 16 cases air studies would have shown appearances indistinguishable from those of a suprasellar tumour, indicating the importance of including carotid angiography in the investigation of suprasellar masses before surgical intervention.

TABLE 4

CAROTID-OPHTHALMIC ANEURYSMS

Position of fundus	Total cases
Above diaphragma sellae	11
Above tuberculum sellae	5
Above plane of sphenoid	1
Above level of anterior clinoid process	6
At level of anterior clinoid process	5
Below level of anterior clinoid process	5
	33

Six of the larger carotid-ophthalmic aneurysms showed retention of the contrast medium within the sac in the film taken two seconds after the injection (cases 5, 13, 16, 25, 26, and 32). Several of these cases showed definite stretching and compression of the terminal part of the internal carotid artery by the large aneurysm, and of the five treated by direct operation all showed a wide neck to the sac of the aneurysm. The phenomenon of retention of the contrast medium in these cases is therefore likely to be a combination of turbulence within the sac and slowed flow in the carotid artery distal to the aneurysm (Fig. 3, a and b). Thus the cause of retention of the contrast medium occurring in some large carotid-ophthalmic aneurysms differs from the sedimentation of contrast medium sometimes seen in cerebral aneurysms with narrow necks, the latter being due to gravitational effect and absence of turbulence within the sac.

MANAGEMENT

As more than one surgeon was responsible for the management of these patients and as this review extends over 15 years, the method of treatment has not been uniform. However, all felt that these aneurysms were no less dangerous to a patient's life than any other intracranial aneurysm and justified surgical treatment whenever possible. From the point of view of management the cases were divided into incidental aneurysms and symptomatic aneurysms (Table 5).

TABLE 5

MANAGEMENT (33* ANEURYSMS)

I	Incidental aneurysms	8
	Operations performed in five cases for offending aneurysm only	
II	Symptomatic aneurysms	25
	Group A: no operation	4
	Group B: carotid ligation only	8
	Group C: intracranial operation	13

* Two aneurysms were present in one patient.

INCIDENTAL ANEURYSMS—EIGHT CASES

In eight cases a carotid-ophthalmic aneurysm was an incidental angiographic finding. Clinical presentation was by subarachnoid haemorrhage in seven cases and by optic nerve compression by a contralateral carotid-ophthalmic aneurysm in the eighth case. The aneurysm responsible for the patient's presenting symptom was identified by specific neurological signs, by radiological evidence of relevant spasm or by the presence of a haematoma. None of the eight aneurysms was treated surgically and the treatment of the offending lesion is shown in Table 6. Case 3 who was admitted in a moribund condition died from a ruptured posterior communicating aneurysm. Case 5 who had bilateral carotid-ophthalmic aneurysms remains well after treating the aneurysm responsible for visual symptoms. Case 6 remains well, her associated posterior communicating aneurysm having been treated by carotid ligation. Case 21 was in a 'moribund' condition from rupture of a middle cerebral aneurysm but remains reasonably well apart from a left hemiparesis. Case 22 died from bleeding of an unrecognised basilar aneurysm after satisfactory clipping of a middle cerebral aneurysm. This case is particularly interesting and is described here in more detail.

CASE 22 This 55 year old lady was admitted on 27 January 1971 after a first attack of subarachnoid haemorrhage. She had no visual symptoms. Examination revealed no localizing signs except for neck stiffness. There was no evidence of a visual field defect and acuity was normal. The ocular fundi were normal as were radiographs of the skull and chest. Bilateral carotid angiography showed both a left carotid-ophthalmic aneurysm and a right middle cerebral

aneurysm. The latter was larger, lobulated, and with an irregular outline, suggestive of the presence of clot, and it was concluded that this was the aneurysm which had bled. The right middle cerebral aneurysm was clipped under hypotension without difficulty. At the end of operation, as she was recovering consciousness, her condition suddenly deteriorated. The wound was reopened and a massive haematoma was evacuated. There was no sign of haemorrhage from the middle cerebral aneurysm. While the wound was being resutured she again bled and rapidly succumbed. A large basilar aneurysm which had ruptured causing massive intracranial haemorrhage was found at necropsy.

Case 27 remains in poor condition after operation on an anterior communicating aneurysm. Cases 30 and 31 are well—the first with conservative treatment and the latter after her right middle cerebral aneurysm had been clipped (Fig. 4).

SYMPTOMATIC ANEURYSMS

GROUP A No operation—four cases (Table 7) Of these cases, case 8, who was in good clinical condition, died before surgery could be undertaken. Case 12, because of the atheromatous condition of the internal carotid artery, was not operated upon. The cause of death at home one year later is not known. Case 14 bled again at the time of angiography and died without regaining consciousness from a massive intracerebral haemorrhage. Further angiography in case 24 showed significant thrombosis within the aneurysm.

GROUP B Carotid ligation—eight cases (Table 8) In these cases common carotid ligation was carried out as an elective procedure. Before operation a satis-

TABLE 6
CASES WITH INCIDENTAL CAROTID-OPHTHALMIC ANEURYSMS

Case no.	Age (yr)	Sex	Offending aneurysm	Treatment	Results and follow-up
3	48	F	(L) Post. com.	None	Died shortly after angiography from further haemorrhage
5	57	F	Contralateral carotid-ophthalmic	Excision of aneurysm	11 yr later no complaint
6	50	F	(L) Post. com.	Carotid ligation	Further haemorrhage 5 yr later causing severe neurological deficit
21	46	F	(R) Middle cerebral	Supportive therapy (Patient grade V)	2 yr later well apart from residual (L) hemiparesis
22	55	F	(R) Middle cerebral	Clipping	Died during postop. period from rupture of unrecognised basilar aneurysm
27	50	F	Ant. com.	Clipping	6 m later gross neurological deficit due to postop. cerebral ischaemia
30	60	M	(L) Post. com. (also has (R) Middle cerebral aneurysm)	Conservative therapy	6 m later no complaint
31	50	F	(R) Middle cerebral	Clipping	4 m later no complaint

FIG. 4 Case 31. Carotid-ophthalmic aneurysm showing irregular outline and filling defects within the sac indicating partial thrombosis in the aneurysm. The neck lies close to the internal carotid artery in all projections. (a) Lateral projection. (b) Anteroposterior half-axial projection. (c) Oblique half-axial projection. (d) Oblique projection through orbit.

TABLE 7
GROUP A (NO OPERATION—FOUR CASES)

	<i>Presenting symptoms</i>	<i>Condition on admission*</i>	<i>Bilateral carotid angiography†</i>	<i>Reasons for withholding surgery</i>	<i>Result</i>
Case 8 47 F	SAH	Grade I	(L) C-Oph. A. L 2 Med B U	Re-bled on 8th day (R) hemiplegia Patient semiconscious	Died
Case 12 62 F	Progressive visual loss	(L) eye VA 6/60 Field defect present Optic atrophy + + (R) eye normal BP 180/100 mmHg	(L) C-Oph. A. L 2 Med U	Poor condition of vessel Hypertension	Died 1 yr later at home No PM
Case 14 38 F	SAH	Grade I	(L) C-Oph. A. L 1 Med B U	Re-bled on 8th day during angiography. Patient comatose	Died
Case 24 18 M	SAH	Grade I	(R) C-Oph. A. L 2 Med U	Further angiography showed almost total thrombosis of aneurysm	Remains well with mild hemiparesis

* Grading according to Botterell's scale.

† Description of carotid-ophthalmic aneurysm.

KEY: Size—Small=S
Medium=M
Large=L

Tip of fundus—1=Above diaphragma sellae
2=Above tuberculum sellae
3=Above plane of sphenoid
4=Above ant. clinoid
5=At level of ant. clinoid
6=Below ant. clinoid

Direction of sac—Medial=Med
Lateral=Lat
Forwards=F
Backwards=B
Upwards=U
Downwards=D

R or L with () indicates side of the aneurysm.
SAH=Subarachnoid haemorrhage.

TABLE 8
GROUP B (TREATMENT BY CAROTID LIGATION—EIGHT CASES)

	<i>Presenting symptoms</i>	<i>Condition on admission*</i>	<i>Bilateral carotid angiography†</i>	<i>Complications</i>	<i>Follow-up</i>
Case 1 31 F	(L) Frontal headache Visual disturbance	(L) eye optic atrophy Field defect present. V.A. No record (R) eye normal 4½ months pregnant	(L) C-Oph. A. S 6 B D	None	13 yr later doing very well (L) eye blind (R) eye normal
Case 2 44 F	SAH	Grade II	(L) C-Oph. A. M 1 Med B U	Postop. (R) hemiparesis Mental confusion	11 yr later doing very well
Case 4 42 F	SAH Transient loss of vision (R) eye	Grade I	(R) C-Oph. A. L 3 Med B U	Postop. (L) hemiplegia	8 yr later died at home No PM
Case 11 44 F	SAH	Grade I	(R) C-Oph. A. M 4 Lat F U	None	7 yr later excellent
Case 15 44 F	SAH	Grade I	(L) C-Oph. A. M 2 Med U D	None	4 yr later excellent
Case 16 45 F	(L) Hemiparesis with facial weakness		(R) C-Oph. A. L 1 Med B U	Hemiparesis got worse	4 yr later doing very well Mild (L) Hemiparesis
Case 18 44 F	SAH	Grade I	(L) C-Oph. A. S 6 F	None	1 yr later excellent
Case 29 47 F	SAH	Grade I	(L) C-Oph. A. M 4 Med B U (L) Post. Com. A. (R) M.C. A.	None	1 yr later excellent

* Grading according to Botterell's scale.

† Description of carotid-ophthalmic aneurysm—see key in Table 7.

factory blood flow to the cerebral hemisphere was ascertained by Matas's test as well as by angiographic cross-flow studies. In some cases transit time studies using ^{99m}Tc were also performed during surgery. Case 1 is in excellent condition although the left eye is totally blind. In two cases there were postoperative neurological deficits and in one case permanent hemiplegia. This patient died at home eight years later of unknown cause. Case 29 with an ipsilateral posterior communicating aneurysm also had a small contralateral middle cerebral aneurysm arising from

one of the perforating branches. As direct surgery was considered technically inadvisable, carotid ligation was performed. This patient remains well one year later.

GROUP C Intracranial operation—13 cases (Table 9) Thirteen patients underwent intracranial operation, the aneurysm being exposed through a subfrontal approach and the method of treatment decided upon after exposure. When the aneurysm could not be clipped it was entrapped in those cases with adequate

TABLE 9
GROUP C (TREATMENT BY DIRECT OPERATION—13 CASES)

	Presenting symptoms	Condition on admission*	Bilateral carotid angiography†	Nature of surgery	Complications	Results and follow-up
Case 5 57 F	Progressive visual failure	(R) eye VA-FC Hemianopia with optic atrophy (L) eye VA—6/12 upper quad. field defect	Bil. C-Oph. A. (R) L 1 Med B U (L) M 5 Med U	(R) Aneurysm excised under hypothermia	None	Very well 11 yr later Vision: (R) 6/36 (L) 6/12
Case 7 37 F	SAH with sudden loss of vision (L) eye	Grade II	(L) C-Oph. A. L 4 Med U	Broad neck partly intra-cavernous entrapped	Transient dysphasia	Very well 10 yr later (L) eye blind (R) eye normal
Case 9 48 F	SAH	Grade I	(R) Post. Com. A. (L) Middle Cerebral A. (L) C-Oph. A. M 4 Med F U	Post. Com. and C-Oph. aneurysms both clipped	None	Very well 10 yr later No complaints
Case 10 55 F	SAH	Grade I	(L) C-Oph. A. L 1 Med B U	Clipped	On 4th postop. day developed (R) hemiplegia ? spasm	Died. PM confirmed ischaemic cerebral infarction
Case 13 22 M	SAH	Grade II	(R) C-Oph. A. L 2 Med U	During clipping aneurysm ruptured	Developed cardiac arrest	Died
Case 17 48 F	SAH	Grade II (L) visual field defect + Acuity normal	(L) C-Oph. A. M 4 Lat U	Clipped	Transient dysphasia	4 yr later doing well apart from sensory disturbance in (R) side of body
Case 19 43 F	SAH	Grade I	(R) C-Oph. A. L 4 Lat B U	Clipped	None	Very well 1 yr later
Case 20 33 F	SAH	Grade I (L) upper quad. field defect	(L) C-Oph. A. M 5 Med U	Aneurysm exposed No attempt to clip. Carotid ligation in neck	None	1 yr later doing well Field defect persists
Case 23 48 F	SAH	(L) eye quad. field defect Acuity: P.L. Disc: atrophy	(L) C-Oph. A. L 1 Med B U	Aneurysm exposed Wrapped with muslin	None	1 yr later vision deteriorated Carotid ligation
Case 25 50 F	Progressive visual failure 10 m Headache 7 yr	Bil. optic atrophy VA—(L) P.L. (R) 2/60	(L) C-Oph. A. L 1 Med B U	Aneurysm excised after trapping the broad neck	Transient dysphasia and (R) hemiparesis	2m later no dysphasia. Mild (R) hemiparesis VA—(L) nil. (R) 6/5
Case 26 61 M	Progressive visual failure Transient (L) hemiparesis	VA—(R) 6/18 (L) 6/12 Bitemp. hemianopia. Both discs pale	(R) C-Oph. A. L 1 Med B U	Neck could not be occluded Entrapped	Developed (R) Hemiplegia	Died. PM—cerebral infarction
Case 28 31 M	SAH	Grade I	(L) C-Oph. A. L 1 Med B U	Clipped	None	Very well. Small part of aneurysm still visible
Case 32 43 F	SAH	Grade I	(R) C-Oph. A. L 1 Med B	Clipped	None	Very well. Small part of aneurysm still visible

* Grading according to Butterell's scale.

† Description of carotid-ophthalmic aneurysms—see key in Table 7.

cross-circulation. In one case (case 23) with poor cross-circulation the aneurysm was wrapped in muslin. One year later the patient had to be readmitted as the aneurysm had suddenly increased in size causing severe optic nerve compression (Fig. 5). The common carotid artery was then ligated in stages. In case 20 the aneurysm was so small and so overlapped by the optic nerve that common carotid ligation was employed. In cases 28 and 32 check angiography showed that about 10–15% of the aneurysms was still visible after clipping (Figs 6 and 7).

Three patients died after intracranial operations. One of these cases (case 10) died from postoperative vasospasm causing cerebral infarction after an apparently satisfactory clipping. Damage to the carotid artery or the neck of the aneurysm was the cause of death in the other two cases. One died from catastrophic bleeding and the other developed cerebral infarction after clipping. Three other cases suffered some form of complication. Case 25 developed a right hemiparesis and transient dysphasia after entrapment and excision of the aneurysm. In case 7 there was transient dysphasia and in case 17 mild dysphasia and sensory disturbance on the contralateral side of the body which are still present four years later.

DISCUSSION

There appears to be a difference of opinion on the exact definition of these aneurysms. According to Drake *et al.* (1968) they arise from the internal carotid artery at the origin of the ophthalmic artery. Kothandaram *et al.* (1971) define them as those which have their origin from the antero-medial wall of the internal carotid artery between the origin of the ophthalmic branch and the point of bifurcation of the internal carotid artery. Guidetti and La Torre (1970) consider them as 'juxtaclinoid aneurysms arising from the medial surface of the carotid artery above the cavernous sinus and below the origin of the posterior communicating artery'. In this series we have included, like Drake *et al.*, only aneurysms arising in the region of the ophthalmic artery. When the neck lies in close apposition to the internal carotid artery the aneurysm may appear to arise distal to the ophthalmic artery origin, but multiple projections at angiography will show its true origin (Fig. 4). Anatomically, the ophthalmic artery most commonly arises from the superomedial aspect of the vessel wall but Duke-Elder and Wybar (1961),

FIG. 5 Case 23. Half-axial projections of large left suprasellar carotid-ophthalmic aneurysm. (a) Before first operation. (b) One year later before second operation. The aneurysm shows further enlargement.

FIG. 6 Case 28. Left carotid-ophthalmic aneurysm with fundus close to dural opening. Pre- and postoperative arteriograms; (a) and (b) Lateral projections. (c) and (d) Oblique projections through orbit. The clip has not completely occluded the sac.

FIG. 7 Case 32. Right carotid-ophthalmic aneurysm and infundibular widening of the origin of the right posterior communicating artery. (a) Oblique projection through orbit. (b) Half-axial oblique projection with head turned towards right side. The neck of the sac is shown in this view. (c) and (d) Pre- and postoperative lateral projections; the clip has not completely occluded the sac.

quoting the work of Linc, Pusznová, and Puzanov, state that it may arise from the inferomedial aspect of the internal carotid artery in 26.7% of subjects and from the inferolateral aspect of the vessel in 13.3%. The inferior origin of the vessel might account for a small number of the aneurysms in this series projecting backwards and downwards from their origin (Figs 7 and 8). In the majority of carotid angiograms, the ophthalmic artery appears to arise from the superior aspect of the internal carotid artery between 1–3 mm distal to the point where this vessel

perforates the dura mater and just proximal to the completion of the backward curve of the carotid siphon. However, as the intracranial part of a normal ophthalmic artery can be seen only in the lateral arteriogram, because of superimposition of the opacified carotid siphon in all other projections, the exact point of origin on the circumference of the internal carotid artery cannot be judged by arteriography.

There seems to be no doubt that these aneurysms have a predilection for the left side (Table 10). Although Guidetti and La Torre

FIG. 8 Case 21. Small right carotid-ophthalmic aneurysm directed downwards, backwards and medially from its origin. An anterior communicating aneurysm is also outlined. (a) Lateral projection. (b) Anteroposterior projection.

TABLE 10
CAROTID-OPHTHALMIC ANEURYSMS

Author	Total aneurysms	Multiplicity		Occurrence on the left side		Occurrence in females		Visual involvement	
		(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Drake <i>et al.</i> (1968)	14	9	64	9	64	12	85	1	7
Guidetti and La Torre (1970)	16	6	37.5	13	81	8	50	8	50
Kothandaram <i>et al.</i> (1971)	19	4	21	12	64	15	80	8	42
Present series (1973)	33	10	32	21	64	26	81	8	24

1970) found no sex preponderance, we are in agreement with other authors that women are more prone to this condition.

Multiplicity is a common factor with these aneurysms. Ten cases in our series had multiple aneurysms, an incidence of 32%, which is about double the accepted overall incidence of multiple intracranial aneurysms demonstrated by bilateral carotid angiography. Only two cases in this series were subjected to vertebral angiography. Drake *et al.* (1968), however, found a much higher incidence of multiple aneurysms. With modern catheter techniques it is probably unjustifiable to omit selective four-vessel angiography in the full investigation of carotid-ophthalmic aneurysms and it is most important in those cases without any definite localizing signs.

Another interesting observation about these aneurysms is that, when found in association with another aneurysm, they are usually asymptomatic. In 10 cases of multiple aneurysms, eight carotid-ophthalmic aneurysms were not responsible for the patients' symptoms. Of the remaining two cases, one patient had also an ipsilateral posterior communicating aneurysm (case 29), with severe spasm of the internal carotid artery. It remains uncertain if the carotid-ophthalmic aneurysm was responsible for this patient's subarachnoid haemorrhage. Only in a case of bilateral carotid-ophthalmic aneurysm was the deterioration in the patient's visual field caused by an aneurysm in this situation. In treating these aneurysms, therefore, it is essential to detect any other aneurysm that could be

responsible for the patient's symptoms. Thus, excluding case 29, in no case of multiple aneurysms was subarachnoid haemorrhage due to bleeding from a carotid-ophthalmic aneurysm.

As far as presenting symptoms are concerned, some important observations can be made. It is true that, in spite of close association with the optic nerve, the incidence of optic nerve compression is small. Out of 32 cases four patients presented with progressive visual deterioration only. In all these cases the size of the aneurysm was more than 60 mm². It would seem that, for the production of visual symptoms, two factors are involved—namely, the direction of the aneurysm and its overall size. One can assume that aneurysms projecting medially would eventually have produced visual symptoms if they had not ruptured while still small in size.

From a study of these cases it appears that their natural history is fraught with danger. Although there were eight cases of incidental aneurysms their follow-up is too short to be able to draw any conclusions about the advisability of treating them. However, once they have produced symptoms they should be treated if at all possible.

When compared with direct surgery, common carotid ligation seems to have produced satisfactory results both in our series and in those cases reported from Salford and Toronto. There is no doubt that, in some circumstances, carotid ligation is a useful form of treatment but it must be realised that, in our series, the good risk cases with satisfactory cross-flow were submitted to carotid ligation rather than to direct surgery. The overall results of direct surgery would probably have been better if such cases had been treated by the direct method. Even in the presence of good cross-circulation there may be a situation where one cannot entirely depend on carotid ligation. Case 25, which has already been described, presented with a visual acuity of 2/60 in the right eye and perception of light only in the left eye. It was felt that to improve her vision the pressure on the right optic nerve must be removed. Cuatico *et al.* (1967) described a large aneurysm of the carotid artery which continued to grow after both common and subsequently internal carotid occlusion. In a series of 58 cases Tindall *et al.* (1966) showed that the sac of the aneurysm was unchanged in 24.1% and larger in 1.7% after carotid ligation. Strenger (1966) suggested that

carotid occlusion may be positively harmful in some cases. He reported two patients in whom optic and oculomotor damage became worse after common carotid occlusion, although angiography in each case showed that the size of the aneurysm had become smaller. Because of these views the aneurysm in case 25 was excised with gratifying improvement in vision. Another objection to advocating routine carotid ligation is the frequent multiplicity of aneurysms in these cases. Unless the presence of another aneurysm is excluded it is undesirable to compromise a large vessel. Finally, the fact remains that not all patients can tolerate carotid ligation and for these patients also, when life or vision is threatened, some form of treatment should be attempted.

In case 13 the aneurysm was torn at the neck during dissection. Since the carotid artery had not been exposed in the neck, by the time this was done the patient had expired from loss of blood. In this context it is worth while to add that occlusion of the common carotid artery does not reduce such serious haemorrhage effectively. Preoperative exposure of the internal carotid artery is preferable.

Another problem in direct surgery is the correlation with angiographic findings at operation. The neck of a carotid-ophthalmic aneurysm may be difficult to clip separately from the internal carotid artery but, as knowledge of the configuration of the neck and the direction of the sac is important to surgical technique, special radiographic projections requiring lateral and half-axial anteroposterior and oblique views are therefore often necessary in order to provide full information (Figs 4, 7, 9, 10). In spite of this, the exact definition of an aneurysm may prove difficult (Morley and Barr, 1969) as only the blood-containing lumen of the sac is visualized. Cases 26 and 23 illustrate this problem. In case 26 a 61 year old man presented with a subarachnoid haemorrhage and progressive deterioration of vision in both eyes from a large carotid-ophthalmic aneurysm. Because of poor cross-circulation, direct surgery was decided upon. Carotid angiography demonstrated that the aneurysm had a good neck and should cause no undue difficulty at operation (Fig. 10). However, during surgery the neck was found to be broad, thick, and adherent to the dura mater. While attempting to define the neck the aneurysmal wall was damaged,

FIG. 9 Case 19. Large right carotid-ophthalmic aneurysm. The neck passes upwards lateral to the anterior clinoid process but also extends proximally to the dural opening. Pre- and postoperative arteriograms; (a) and (b) Lateral projections. (c) and (d) Half-axial anteroposterior projections. (e) and (f) Oblique projections through orbit. After clipping, a small portion of the neck of the aneurysm close to the dural opening remains unoccluded.

FIG. 10 Case 26. Large right carotid-ophthalmic aneurysm. The fundus of the sac lies in mid-line supra-sellar position. The neck of the sac is wide and extends through the dural opening. (a) Lateral projection. (b) Half-axial anteroposterior projection. (c) Half-axial oblique projection. The aneurysm extends backwards and upwards medial to the right anterior clinoid process.

necessitating the entrapment procedure. The patient died from cerebral infarction, and necropsy revealed that the aneurysm was much larger than shown on angiography and that part of its neck was extradural. In case 23, again because of poor cross-circulation, the patient was submitted to direct surgery. From a study of the angiogram it was felt that in spite of its large size the aneurysm could be controlled by occlusion of its neck (Fig. 5). However, at operation the situation appeared completely different. The aneurysm proved to be a very large 'blow-out' of the internal carotid artery. The distal part of the artery beyond the aneurysm looked like the thread

of an inflated balloon. There was no alternative but to wrap the aneurysm in muslin. Because of the extradural extension of the neck of the aneurysm in some cases total obliteration by clipping is not possible. This was demonstrated by check angiograms in two of our cases (Figs. 6 and 7). As there is no information about post-operative angiograms in the reported series, nor in our early cases, the real incidence of total obliteration of these aneurysms remains uncertain.

Contrary to the commonly held view that the larger the sac the thicker is its wall, in some of these large aneurysms the wall was extremely

thin. In several cases the aneurysmal wall was so thin that blood could be seen churning within the sac. Manipulation of this type of sac for the purposes of occlusion could be disastrous. Elective hypotension to a systolic blood pressure of about 55 mmHg with ganglion blocking agents, and provision for temporary occlusion of the carotid artery in the neck are useful in the prevention of rupture during the application of the clip. Thus, even when the aneurysm leaks, the flow can be contained in the sucker tip giving an opportunity to apply the clip satisfactorily. The high speed dental drill for enlargement of the optic foramen and the use of the operating microscope are recent technical aids which facilitate surgery. It remains to add that the surgeon must be prepared to decide after exposure that a particular aneurysm is not amenable to direct attack. We agree with Drake's view when he advises that the surgeon should be prepared to retreat with the same courage with which he first made the decision to operate. Finally, it must not be forgotten that the aneurysms which project laterally do not present any of the special difficulties mentioned above. They can be obliterated by the intracranial method like any other aneurysm as shown in Fig. 9.

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