Diagnosis by ultrasound of severe carotid artery disease in patients undergoing cardiopulmonary bypass operations

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SUMMARY A non-invasive method using continuous wave Doppler shift ultrasound and spectral analysis was used as a screening test for severe carotid artery disease in patients undergoing cardiopulmonary bypass operations. One hundred and eighty-eight patients were examined before cardiac surgery (91 for ischaemic heart disease, 17 for ischaemic heart disease and valve replacement, 66 for valve replacement alone, and 14 for congenital abnormalities). The mean age of the 108 patients suffering from ischaemic heart disease was 54 years (± 8) and that of the 80 patients admitted either for valve replacement alone or for congenital abnormalities was 52 years (± 12). Five of the 108 patients suffering from ischaemic heart disease were found to have severe occlusive disease of the internal carotid artery by the ultrasound test, while the test was normal in the other two groups. Patients with severe carotid artery disease proceeded to carotid arteriography and endarterectomy before the planned heart operation.

Symptoms of cerebrovascular ischaemia are a well-recognised complication of open heart operations.¹⁻³ One explanation of such symptoms is that during surgery the blood pressure may be lowered on occasions to 40 mmHg or less and if severe occlusive carotid artery disease coexists this results in reduced cerebral perfusion.⁴ This is likely to occur because occlusive arterial disease is often a generalised condition and both carotid and coronary arteries are favoured sites for the deposition of atheroma. The number of patients requiring open heart surgery is increasing, especially for treatment of ischaemic heart disease, and with the improvement in surgical techniques operations on older subjects are now undertaken.^{5 6} There is, therefore, likely to be an associated increase in the incidence of postoperative complications resulting from carotid artery disease. Before this study was undertaken two patients in our department had recently died after operation without regaining consciousness despite no obvious complications occurring during cardiopulmonary bypass and necropsy showed severe, undiagnosed carotid artery disease in both cases.

Kartchner and McRae⁷ have reported the value

of oculoplethysmography for preoperative assessment of the carotid arteries in 216 patients undergoing operative procedures involving the heart, abdominal aorta, or arteries of the lower limb. Seventy-two patients were shown to have severe carotid artery disease, 35 of whom proceeded to carotid endarterectomy before the planned procedure and experienced no complications of cerebrovascular ischaemia from either operation. The remaining 37 patients in this group did not have a carotid endarterectomy and seven (19%) developed symptoms of cerebrovascular ischaemia after the planned operation.

Any non-invasive method used for assessing occlusive disease of the carotid arteries should identify those patients with a lesion severe enough to reduce distal mean pressure in the internal carotid artery. This paper is a report of our experience using Doppler shift ultrasound and spectral analysis^{8 9} for this purpose in patients undergoing open heart surgery.

Subjects and methods

A total of 188 patients was assessed; 108 (94 men and 14 women) suffered from ischaemic heart

disease and were admitted for aortocoronary bypass graft operations, and 80 patients (40 men and 40 women) required open heart surgery for valve replacement or congenital abnormalities. The mean age of the first group was 54 years (± 8) and that of the other group 52 years (± 12). Twenty-three had suffered from transient ischaemic attacks or had a localised carotid bruit, or both, as shown in Table 1.

The Doppler assessment was performed with the patient unsedated and lying supine on a couch. A Parks 805 blood velocimeter (10 MHz) was used to record Doppler shift signals from the supra-orbital artery and the carotid bifurcation. This velocimeter was modified by the addition of a phase resolver¹⁰ to permit simultaneous presentation of blood flowing towards and away from the transducer, thus providing information about the direction of blood flow in the insonated artery even in the presence of interference from venous signals. The transducer was placed on the skin overlying the artery of interest and backscattered signals from erythrocytes were immediately displayed by a spectral analyser⁸ in sonogram form (Fig. 1).

The screening procedure consisted of insonating the supraorbital artery and observing the shape of the sonogram and direction of blood flow, both of which indicate whether disease is present.⁹ The temporal artery occlusion test described by Brockenbrough¹¹ was modified¹² and used to detect lesions severe enough to cause a reduction in distal mean pressure in the internal carotid pathway. This test relies on the fact that normally there is equal pressure in the internal carotid and external carotid arteries. These two vessels usually form an anastomotic vascular bed in the region of the forehead via collateral vessels from the supraorbital and superficial temporal arteries, and in the normal situation there is a pressure gradient between the supraorbital artery and this collateral bed such that blood flows out of the orbit. If the pressure in the superficial temporal artery is reduced by digital compression there is a greater pressure gradient

Fig. 1 Normal sonogram from the common carotid artery over one cardiac cycle. Doppler shift frequency is on the Y-axis and time is on the X-axis. The blackness of the trace at any point is related to the number of erythrocytes generating the same Doppler shift (that is moving at the same velocity).

and erythrocyte velocities increase in the supra-orbital artery (Fig. 2). However, if disease is present in the internal carotid artery sufficient to cause a reduction in distal mean pressure, blood flows into the orbit from the superficial temporal artery which is then at a higher pressure than the supraorbital artery. In this situation compression of the superficial temporal artery will usually stop or significantly reduce flow from the external carotid pathway into the supraorbital artery (Fig. 2). The presence of other collateral vessels may cause inaccurate results and we therefore compress other branches of the external carotid arteries both separately and simultaneously; these principally include the ipsilateral facial artery and contralateral superficial temporal and facial arteries.

The carotid bifurcation was then insonated, and when severe disease was present near the origin of the internal carotid artery high-velocity or turbulent Doppler shift signals⁹ were usually obtained. The absence of a signal from the internal carotid artery indicated that this artery was totally occluded.

The presence of severe carotid artery disease shown by the non-invasive investigation was

Table 1 Patients assessed using ultrasound for carotid artery disease before cardiopulmonary bypass surgery

Operation	Patients examined				
	No. of patients	Transient ischaemic attack (TIA)	Neck bruit transmitted from heart	Localised carotid bruit (LCB)	TIA and LCB
Coronary artery bypass graft (CABG)	91	6	0	5	1
Valve replacement (VR)	66	9	22	0	0
CABG and VR	17	1	7	2	1
Congenital abnormality	14	0	4	0	0
Total	188	16	33	7	2

confirmed by carotid arteriography and an endarterectomy was performed six to eight weeks before open heart surgery.

Results

(1) ULTRASOUND SCREENING TEST

A summary of the 188 patients in this study is shown in Table 1, and in Table 2 are details of the

five patients found to have severe internal carotid artery disease by the ultrasound examination. A diagnosis of bilateral severe disease was made in case 5, with complete occlusion of the left internal carotid artery.

(2) CAROTID ARTERIOGRAPHY

The ultrasound diagnosis was confirmed by carotid arteriography in four patients (cases 1 to 4). Total

Fig. 2 Above: Diagrammatic illustration of the anastomotic vascular bed between the internal and external carotid arteries in the forehead. The temporal artery occlusion test is performed by insonating the supraorbital artery and compressing the ipsilateral superficial temporal artery against the cranium. Below: Sonograms demonstrating a normal temporal artery occlusion test (top line) with augmentation of flow-velocities during compression. In an abnormal test (bottom line) blood flows initially into the orbit and is stopped by compression. In the case illustrated some blood then flows out of the orbit, indicating additional collateral supply to the internal carotid pathway.

occlusion of the left internal carotid artery was confirmed in case 5, but on the right side the angiogram showed only minor lesions at both the origin and siphon of the internal carotid artery.

No complications occurred as a result of arteriography.

(3) SURGERY

Of the five carotid endarterectomies performed in patients shown to have severe disease by the ultrasound technique the only complication was in case 2 who had a left carotid endarterectomy and developed mild weakness of the right arm after the operation.

In case 5, though the right carotid arteriogram demonstrated only a 14 per cent reduction in lumen diameter, an endarterectomy was performed as the patient had had recent transient ischaemic attacks and the non-invasive investigation indicated that severe disease was present. This disagreement between the ultrasound and arteriogram result could have been partly explained by disease being present at more than one site, but may also have been a result of the α -ray image underestimating the size of the lesion at the origin of the internal carotid artery. This proved to be the case as at operation severe disease was found at the carotid bifurcation.

After open heart surgery one of the five patients died without regaining consciousness and necropsy disclosed a recent myocardial infarct. There were no cerebrovascular complications after cardiac surgery in the other patients who had had a carotid endarterectomy.

Discussion

An interesting finding in this study was that severe carotid artery disease was not found in patients who did not suffer from ischaemic heart disease, though the mean age of this group was similar to that of the group with the ischaemic heart disease. Five

per cent of patients suffering from ischaemic heart disease were found to have severe occlusive lesions in the internal carotid artery. This finding accords with other reports that there is an association between the presence of occlusive arterial disease in the coronary and carotid arteries.^{13 14} Though in this study carotid endarterectomy was undertaken some weeks before the heart operation, the two operations have been performed at the same time.^{15 16}

This study confirms the limitations of relying on the presence of either a localised bruit in the neck or symptoms of cerebrovascular disease as indicators of severe occlusive disease of the carotid arteries.^{9 17 18} A localised bruit was not present in three of the five patients with a severe internal carotid lesion (Table 2). In another patient one internal carotid artery was completely occluded but bilateral carotid bruits were present, and the fifth patient had only minor disease on the side of the bruit but severe disease on the contralateral side. The use of spectral analysis allows the examiner to know in which artery a bruit originates¹⁹; one patient with ischaemic heart disease who had not suffered from neurological symptoms had a localised carotid bruit and the ultrasound investigation demonstrated disease in the external carotid artery. Two patients with severe lesions in the internal carotid artery suffered from transient ischaemic attacks and only one of these had a carotid bruit associated with these symptoms. However, 14 other patients had also suffered from transient ischaemic attacks, and ultrasound showed no evidence of severe disease. Furthermore, two patients with severe internal carotid artery disease had no signs or symptoms of cerebrovascular disease.

In this study bilateral carotid arteriography was performed, but as confidence increases in the ultrasound diagnosis unilateral arteriography may be sufficient when ultrasound shows the presence of severe disease on one side only. An ultrasound vessel imaging system²⁰ is now being used for

Table 2 Details of patients shown by ultrasound to have severe internal carotid disease

Case no.	Heart operation	Age (y)	Sex	Side with localised carotid bruit	Transient ischaemic attacks—carotid territory implicated	Side with severe disease diagnosed by ultrasound	Estimated reduction of lumen diameter on arteriograms of side with severe disease diagnosed by ultrasound
1	Coronary artery bypass graft (CABG) and valve replacement	56	M	—	—	L	79%
2	CABG	57	F	—	L	L	52%
3	CABG	61	M	—	—	R	33%
4	CABG	51	M	R	—	L	83%
5	CABG	44	M	R and L	R and L	R and L	R, 14% L, 100%

further confirmation of the presence of disease at the carotid bifurcation, so that in cases of total occlusion of the internal carotid artery the non-invasive investigation may obviate the need for arteriography and allow precautions to be taken during open heart surgery.

Non-invasive assessment of the extracranial cerebral arteries using Doppler shift ultrasound and spectral analysis is a safe and relatively easy investigation to perform. It can be performed on an outpatient basis, has no contraindications, and the costs are approximately 10 per cent of those for arteriography. We suggest that this is a valuable preoperative investigation for all patients undergoing open heart surgery for ischaemic heart disease. However, the case for carotid endarterectomy as a treatment for both haemodynamically significant and minor carotid artery disease in these patients has still to be established in further studies.

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