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I W Turnbull

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Isotope Cerebral Perfusion Studies before and after Extracranial/Intracranial Bypass

I. W. Turnbull[1]

A quick, inexpensive, and reliable method of estimating cerebral perfusion is described that uses simple gamma camera and computer facilities readily available in almost all neuroradiology departments. Eighty-eight patients with unilateral cerebral ischemia were studied who satisfied the criteria for inclusion in the international cooperative study for extracranial/intracranial arterial anastomosis. The results of their isotope cerebral perfusion studies were compared with their computed tomographic scans and cerebral angiograms. The aims of the study were: (1) to ascertain whether the isotope study could predict the presence of a stenosis or occlusion; (2) to determine whether it could forecast the presence of a collateral blood flow and allow an assessment of the contribution of the collaterals to the overall cerebral perfusion; and (3) to assess the patency of the extracranial/intracranial bypass and monitor the effects of that procedure on hemisphere perfusion. The results show that this examination does predict the angiographic findings in nearly all patients and provides useful information about the natural collateral blood flow so that appropriate surgical treatment can be planned for the patient. The changes in cerebral perfusion after bypass were correlated with postoperative angiograms and offer a possible means of assessing and monitoring the effects of revascularization surgery and its contribution to the perfusion of that hemisphere.

For some years stroke research has been directed toward elucidating the possible role of carotid stenosis and occlusion in the etiology of cerebral infarction. Clinical interest in this relationship followed on the classic work of Fisher [1, 2], who found stenosis and occlusion of the internal carotid artery in the neck to be common among cases of cerebrovascular accident. Subsequently, Lhermitte et al. [3] attributed 40% of middle cerebral artery territory infarcts to thrombosis of a previously stenosed carotid artery. Other workers have been less enthusiastic about the association and have found a carotid occlusion in less than 20% of their patients after cerebral infarction [4].

Carotid endarterectomy and more recently revascularization surgery have been developed as therapeutic tools to deal with the problems of cerebral ischemia associated with carotid stenosis and occlusion [5]. In evaluating patients thought likely to benefit from extracranial/intracranial bypass surgery, it is important to have some knowledge of the overall cerebral perfusion and of the contribution made to it by a collateral blood flow, if present. This paper details a simple noninvasive isotope technique and its application in the assessment of patients undergoing extracranial/intracranial bypass.

Subjects and Methods

Eighty-eight patients with unilateral cerebral ischemia who satisfied the clinical criteria for inclusion in the international cooperative study for extracranial/intracranial arterial anastomosis were admitted to the study. All patients underwent computed tomography (CT) and cerebral angiography. If a stenosis or occlusion of an internal carotid artery or one of its major branches was found, an angiographic assessment of collateral flow to the affected hemisphere was made, special attention being paid to any contribution from the contralateral carotid system and the vertebrobasilar arterial tree and from any naturally occurring extracranial/intracranial anastomosis.

Each patient was subjected to a simple isotope assessment of cerebral perfusion using the following technique. A 1–2 ml bolus of 700 MBq ^{Tc}99m pertechnetate was injected into a peripheral arm vein followed by a 10–20 ml flushing injection of isotonic saline solution. A gamma camera with a high-resolution collimator placed over the vertex of the skull recorded the subsequent emission during the first pass through the cerebral circulation. The recording was monitored by computer and so arranged that 1 sec frames were obtained throughout the study.

Following collection of the data, regions of interest were described within each hemisphere to correspond to the estimated areas usually supplied by the anterior and middle cerebral arteries. Computer analysis of gamma emission relative to time was graphically displayed for each region of interest. The dynamic curves so obtained were normalized for area and smoothed. The peak value (P value) was noted for each hemisphere. This is the length of time, in seconds, taken to achieve the maximum count rate for each region of interest. It is an arbitrary figure that allows comparison between the two hemispheres. When there was a delay of one or more seconds in achieving this maximum, a stenosis or occlusion of the internal carotid artery or one of its major branches was predicted.

Similarly, it is possible for the computer to measure the maximum count rate within each region of interest and to express this as a percentage. The clinically normal hemisphere was designated as 100% and the clinically affected side as a percentage relative to this. The results of the isotope studies and the predictions arising therefrom were never available to those performing or assessing the angiography. The data from the isotope cerebral perfusion studies were subsequently compared with the CT scans and angiograms.

Thirteen of the 88 patients subsequently had an extracranial/intracranial bypass operation. Three months later, they had repeat isotope, CT, and angiographic studies and these were again compared for each patient and with the preoperative data. The aims of the study were: (1) to ascertain whether the isotope study could predict the presence of a stenosis or occlusion of the internal carotid artery or one of its major branches; (2) to determine whether

[1]Department of Radiology, North Manchester General Hospital, Delaunays Road, Crumpsall, Manchester, M8 6RB, England.

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it could forecast the presence of a collateral flow and allow an assessment of the contribution of the collaterals to the overall cerebral perfusion; and (3) to monitor the effect of the extracranial/intracranial bypass on hemisphere perfusion and see whether the isotope study could predict bypass patency.

Results

Of the 88 patients, 60 had an entirely normal isotope study and in all of these patients angiography was also normal. In the other 28 patients the isotope study revealed a delay of one or more seconds in achieving maximum perfusion of a hemisphere (P value) and a stenosis or occlusion of the corresponding internal carotid artery or one of its major branches was predicted. This was confirmed at angiography in 27 of these, there being one false-positive.

In these 27 patients, the isotope percentage perfusion to the affected hemisphere was correlated with the demonstration of collaterals at angiography. When the percentage perfusion was less than 85% relative to the normal side, collateral flow to that hemisphere was assessed at angiography as being poor or absent in all cases. In the eight patients with an isotope perfusion of 85%–89%, collaterals were graded as poor or absent in four and moderate in four.

By contrast, if the isotope perfusion exceeded 90%, as was the case in 16 patients, collateral blood flow was recorded as good or excellent in 14 of these. The two other patients recorded a moderate collateral flow, but in both of them CT depicted an area of established infarction when one might expect a reduction in overall perfusion to that hemisphere. It was therefore concluded that, provided CT did not disclose evidence of infarction, the isotope percentage perfusion figures could allow a forecast to be made of probable collateral blood flow as determined at angiography.

Following extracranial/intracranial bypass in 13 patients, the change in isotope percentage perfusion to the affected hemisphere was correlated with pre- and postoperative perfusion as seen on angiography. An attempt was also made to predict bypass patency (table 1). In five patients the difference between the pre- and postoperative isotope examinations was less than 5%. In three of these, no demonstrable change in overall perfusion was observed on the follow-up angiograms and in two patients there was a slight reduction. The bypass remained patent in four of the five however.

The other eight patients showed an increase in isotope perfusion of more than 5%, and, in all but one of these, the overall perfusion was observed to have increased at angiography. It was unaltered in the other one and the bypass was patent in all eight patients. It was concluded that the isotope study could not predict bypass patency, but could accurately reflect and monitor changes in overall perfusion to a hemisphere after an extracranial/intracranial bypass.

The angiographic data also suggested that when a bypass remained open and the overall perfusion to that hemisphere consequently increased, the naturally occurring collateral blood flow remained the same in most patients. If confirmed in a larger series, this finding would console those who fear that a well functioning bypass might compete with the natural collateral blood flow perhaps causing an unfavorable reduction in the latter.

Finally, the prebypass isotope perfusion data were compared with the change in angiographically determined perfusion to that hemisphere after a bypass procedure (table 2). A trend seemed to emerge that suggested that when the isotope perfusion exceeded 95%, as it did in six patients, the bypass made little, if any, difference in the overall perfusion, remaining unaltered in four and actually diminishing in two. By contrast, a preoperative isotope perfusion of less than 90% was associated with an increase in hemisphere perfusion after extracranial/intracranial bypass.

TABLE 1: **Comparison of Isotope Studies with Angiography before and after Extracranial/Intracranial Bypass**

	Change after Bypass:	
In Isotope Perfusion: Case No.	In Overall Hemisphere Perfusion on Angiography	In Natural Collateral Blood Flow
Unaltered:		
1	Diminished	Increased
2	Unaltered	Unaltered
3	Unaltered	Unaltered
4	Unaltered	Diminished
5	Diminished	Diminished
Increased:		
6	Increased	Unaltered
7	Increased	Unaltered
8	Increased	Unaltered
9	Increased	Unaltered
10	Increased	Unaltered
11	Unaltered	Unaltered
12	Increased	Increased
13	Increased	Diminished

Note.—The bypass was not patent in case 1. In all other cases, it was patent.

TABLE 2: **Correlation of Prebypass Isotope Perfusion Data with Subsequent Postbypass Angiographic Assessment of Hemisphere Perfusion**

Prebypass Isotope Perfusion	No. of Cases			
	Totals	Postbypass Hemisphere Perfusion at Angiography		
		Increased	Unaltered	Diminished
<85%	2	2	0	0
85–89%	4	4	0	0
90–94%	1	1	0	0
95–99%	3	0	2	1
>100%	3	0	2	1

Discussion

A technique has been described that is inexpensive, readily available in almost all neuroradiology departments, and easy to perform. Four main points emerged from this study: (1) The isotope study described can predict the presence of a stenosis or occlusion of the internal carotid artery in patients presenting with clinically unilateral cerebral ischemia. (2) In the presence of a carotid stenosis or occlusion it is possible to forecast the likely collateral blood flow. This can be done provided that CT does not disclose an established infarct or an acute enhancing infarct. Under these circumstances the isotope study would underestimate or overestimate the collateral flow, respectively. (3) After extracranial/intracranial bypass, the isotope examination cannot predict bypass patency but does reflect and monitor changes in overall perfusion. (4) A trend emerged suggesting that a bypass procedure might only benefit those patients with an initially poor collateral blood flow and be of marginal benefit when the natural collateral blood flow was already good or excellent. The isotope cerebral perfusion study might be used to select such patients if future studies could confirm this trend. It is suggested that the isotope perfusion technique be used as an initial study to screen patients presenting with clinically unilateral ischemia. The data may then be used to determine the need for angiography and possibly select patients suitable for revascularization surgery.

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