Short report

Continuous wave Doppler ultrasonography in the detection of carotid stenosis and occlusion

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Summary Directional continuous wave Doppler ultrasonography has been used to assess the extracranial carotid arteries of over 500 patients, 90 of whom have had angiography performed. The angiographic and Doppler findings are compared, showing that this simple ultrasound technique is able to detect carotid stenosis and occlusion, but is unreliable in the detection of mild atheromatous change. In this series, the method detected 90% of the angiographically proven carotid stenoses, being considerably more accurate than routine auscultation. It would seem that continuous wave ultrasonography is a safe and practical screening test in those patients in whom arteriography is being considered.

About 20%–30% of patients with carotid transient ischaemic attacks (TIAs) referred to a neurological centre are found to have a surgically correctable lesion;1 the majority of the patients thus undergo unnecessary and potentially hazardous angiography. This is one of the factors responsible for the marked variation in the percentage of patients undergoing angiography for the investigation of TIAs in different centres throughout the United Kingdom (3 to 100%).2 Prior to the introduction of digital vascular imaging, ultrasound formed the basis of most of the techniques used for the non-invasive investigation of the carotid arteries as a preliminary to angiography. Over the past two years continuous wave Doppler ultrasonography has been used at this hospital to assess such patients. The results have been compared with the findings of conventional angiography, and with the presence of a carotid bruit, which is the most reliable clinical guide to carotid stenosis.3 4

Methods

A continuous wave directional Doppler flowmeter using transducers with non-focused beams of 4 and 8 MHz (System Sonotechnik model LC2) was used to assess the flow profiles in the supraorbital and supratrochlear arteries around the eye, and the flow in the extracranial carotid arteries in the neck, in order to screen for haemodynamically significant stenoses and occlusions in these vessels.5 7 9

In continuous wave ultrasonography, high frequency sound waves are reflected by moving red blood cells causing an associated Doppler shift; the degree of this shift is proportional to the velocity of the blood. In the presence of a stenosis, the velocity of red blood cells through the narrowed segment rises, producing an increase in the Doppler shift. This may be the only abnormality in a mild stenosis. Tight stenotic lesions situated in the internal carotid artery can also produce a reduction in the flow in the ipsilateral common carotid artery detectable with this technique. The supraorbital and supratrochlear arteries constitute part of the watershed circulation between the internal and external carotid arteries; the direction of the flow in these orbital vessels is dependant on the peripheral resistance in the carotid arteries. As the pressure in the ophthalmic artery is normally greater than that in the terminal branches of the external carotid artery, the normal flow in the supratrochlear and supraorbital arteries is out of the orbit. However, if a haemodynamically significant stenosis is present in the internal carotid artery, the perfusion pressure to the ophthalmic artery may be progressively reduced and may eventually fall below the perfusion pressure in the branches of the external carotid artery, thereby reversing...
flow in the supraorbital and supratrochlear arteries. The
detection of such altered perfusion is greatly facilitated by
digital compression of the superficial temporal and facial
arteries, which by temporarily reducing the pressure from
the external carotid artery may unmask low internal or
dominant external carotid flows. This study combined
analysis of the supraorbital, supratrochlear and the com-
mon, internal and external carotid artery signals, as
described above, to detect haemodynamically significant
lesions at various sites in the extracranial carotid arteries.

Over the past two years Doppler studies have been per-
formed on over 500 patients at this hospital. Of these, 90
came to angiography, most having conventional catheter
angiograms but six having digital vascular imaging. The
angiograms were reviewed blind by a consultant neuro-
radiologist, unaware of the Doppler findings. The internal
common carotid artery was classified as normal, occluded, stenosed
(31–99% narrowing) or atheromatous (up to 30% narrowing); these results were compared with the Doppler
findings, as was the presence of a carotid artery bruit on
clinical examination.

Results

Correlation with angiography

Angiographic results were available for 154 carotid
arteries. Twenty-five vessels with arteriographically
proven carotid occlusion were correctly diagnosed by
Doppler study (table). The one false positive
result, in which no signal was detected from the
internal carotid artery suggesting occlusion, was
found on angiography to be due to a normal extracra-
nial segment to the internal carotid artery with a
tight intracranial stenosis producing a marked
reduction in flow in the proximal segment.

Of the 39 vessels with angiographically proven
internal carotid artery stenosis, 35 were correctly
diagnosed by Doppler study. There were four false
negatives in this group in which arteriography
showed stenotic lesions. In all four cases, turbulence
suggestive of atheroma was noted but no high fre-
cquency stenotic signal detected. In the one false
positive case in this group a high frequency stenotic
signal was detected, but angiography showed severe
atheroma but no stenosis.

Table The Doppler and angiographic findings of the
internal carotid artery in 154 carotid arteries (90 patients)

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<th>Carotid occlusions</th>
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<td>Carotid stenosis (31–99% narrowing)</td>
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In those patients with angiographically proven
mild atheroma, the Doppler and angiographic
findings agreed for 15 vessels. In the nine false posi-
tive results, turbulence suggestive of atheroma was
present on Doppler examination, but angiography
showed either minimal atheroma or a normal vessel.
In the 13 false negative cases, the Doppler result
was normal, but angiography showed clear
atheroma. However, in no case was a significant
stenosis found. In 51 arteries both the Doppler and
angiographic findings were normal.

Correlation with bruits

Of the 39 arteries with carotid stenoses on angio-
graphy, a carotid bruit was only present in 27. In the
12 "bruit negative" examples, three had severe
stenoses (greater than 90%), six had moderate steno-
oses (65–90%) and three had mild stenoses (31–
50%). The Doppler study correctly detected nine of
these 12 "bruit negative" stenoses.

There was 13 false positive results, of which two
had normal angiograms, four showed irregularity of
the internal carotid only, three had an external
carotid stenosis and four had internal carotid occlu-
sions (two being on the same side as the bruits and
two on the opposite side of the bruit). Doppler study
correctly assessed 12 of these 13 false positive
bruits. The one incorrectly assessed bruit, thought
on Doppler study to represent an internal carotid
artery stenosis, proved on angiography to be an
external carotid artery stenosis.

Discussion

The continuous wave Doppler technique used in this
study has been shown to be effective in detecting
carotid stenoses and occlusions, confirming the
findings of Hennerici et al. In our study all 25
patients with carotid occlusions were successfully
detected with one false positive result. Of the 39
patients with internal carotid artery stenoses near
the bifurcation, 90% were correctly detected. How-
ever, the technique described herein is of limited use
in the detection of mild atheromatous disease. The
more refined ultrasonic methods combining Doppler
flow and echo imaging techniques enable the visual-
ization of mild degrees of atheroma in addition to
giving information about flow. However, these
techniques are considerably more expensive and for
many situations a simple Doppler flowmeter is all
that is required to give useful information with
regard to possible carotid occlusion and stenosis.

Carotid angiography remains the standard techni-
que for the investigation of the carotid arteries in
patients with TIAs. However, the techniques still
have a small but significant morbidity, usually esti-
mated at about a 1% risk of stroke or death. However, a recent prospective study in which each patient was assessed by a neurologist suggests that the risk may be as high as 5%.\textsuperscript{11} Digital vascular imaging may lessen these risks but, unfortunately, the technique does not produce adequate views of the carotid bifurcation in all patients.\textsuperscript{12}

Because of the risks, many clinicians will only submit patients to angiography if it is felt that a stenosis is likely to be present on the basis of clinical history and examination. A localised bruit is the best clinical guide. This study, in addition to others,\textsuperscript{6} has shown that the presence of a bruit is of limited value. Whilst a bruit was present in 27 (69% of our patients with internal carotid stenosis), 12 (31%) patients were without a bruit. The Doppler examination correctly detected nine of these 12 false negatives. Furthermore, there were 13 false positive bruits, of which 12 were correctly assessed by this technique. Thus of the 25 false negative and false positive bruits in this group the Doppler was correct in 21 cases. The technique was, therefore, clearly superior to auscultation of the neck. The method, and in particular the handling of the transducers, is very much operator sensitive. However, with suitable supervision the authors feel that it is possible to become reasonably competent after approximately 100 studies. Ultrasonic methods have been shown to be increasing accurately in the assessment of extracranial carotid artery disease. In our opinion it proves a safe, simple and cheap screening test helping clinicians to decide when angiography would be likely to reveal carotid stenoses and occlusions.

We are deeply indebted to Dr Michael Hennerici who was instrumental in helping us to master this technique over his 3 months stay at The National Hospital. We thank Dr John Stevens for assessing the carotid angiograms and Professors J Marshall and WI McDonald for their help and encouragement with this project.

References

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