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CAROTID DOPPLER IN THE MANAGEMENT OF STROKE

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INTRODUCTION:

Atherosclerosis is the most common cause of extracranial cerebral arterial stenosis, but its cause and pathogenesis remain largely unresolved 1. The role of extracranial carotid lesions in the pathogenesis of ischemic stroke was described as early as 1856 by Savoury[2], and carotid-to-brain embolism was described by Chiari in 1905[3], but it was Fisher[4] who recognized that the two basic mechanisms causing focal cerebral ischemia from carotid artery disease are embolization and decreased flow through the carotid artery.

Plaques occur preferentially at the carotid bifurcation on the outer and lateral arterial walls either where shear stress is highest[5] or where shear stress is low and flow-dependent lipids accumulate. The growth of these plaques and ensuing disintegration, surface ulceration, and thrombosis determine the pattern of subsequent symptoms. Therefore, knowledge of the site and degree of stenosis are critical to clinical decision making in patients with ischemic cerebral symptoms.

Carotid Doppler is an accurate, safe and repeatable method of assessing arterial caliber and to identify the stroke-prone individual. It is completely non-invasive and can be used serially to monitor progression in carotid stenosis. It is a valuable clinical tool in diagnosis and management in patients at risk of stroke, but has definite limitations, such as in differentiating carotid occlusion from severe stenosis.

Doppler ultrasound technology has advanced rapidly in the last decade, especially in the combination of B-mode imaging and Doppler (duplex), as well as in evaluation of the intracranial circulation (transcranial Doppler). In the next decade, it may become the new gold standard for evaluating the extracranial circulation.

PREVALENCE OF ASYMPTOMATIC INTERNAL CAROTID ARTERY STENOSIS

Knowledge of the prevalence of carotid arterial disease in the general population would facilitate a rational management of asymptomatic carotid lesions. Carotid Doppler ultrasound examination allows community screening for carotid arterial disease.

In unselected asymptomatic volunteers, the prevalence of stenosis over 50% was low (3.7%) and over 80% was approximately 1%[6] . However, carotid stenosis is clearly present in an appreciable number of asymptomatic subjects over age 50, and increases with age, but carotid stenosis extensive enough to produce hemodynamic compromise is rare, probably less than 1% in most populations.

Since its introduction in 1927 by Moniz[7], cerebral arteriography has been considered the only acceptable method for quantifying in vivo the extent and severity of atherosclerotic lesions. However, in addition to the cost, length of the procedure and patients discomfort, a major concern about angiography is its safety since it still carries a morbidity and mortality risk of 0.6-1.0% which precludes its repetitive application[8]. Recent advances in non-invasive techniques such as Doppler ultrasound have considerably improved and extended the capacity for assessing progressive changes in carotid bifurcation. The technique is non-invasive, easily repeatable and without any discomfort or risk for the patient. However, the main challenge and demand for each carotid Doppler laboratory is to evaluate the validity or accuracy and reliability or reproducibility of their test procedure.

ACCURACY OF CAROTID DOPPLER

The principle of Doppler ultrasonography is that an ultrasound beam emitted by crystals in the Doppler probe (applied to the skin over an artery) is reflected back by the moving column of blood. The frequency difference between the emitted and received signals is the "shift", measured in kHz. The faster the blood moves, for instance through an area of stenosis, the greater the shift.

The emitted ultrasound signal may be continuous ("continuous wave") or may be emitted in short bursts ("pulse wave"). The combination of real-time imaging of the artery (B-mode) and Doppler ultrasound is termed "duplex scanning". B-mode imaging shows a magnified picture of the arterial wall, demonstrating the shape, size and consistency of the plaque. However, it is not an accurate method of assessing stenosis which is still best measured by Doppler method. For detecting serial changes in the arterial caliber (i.e. progression), a basic requirement is to evaluate the reliability of the diagnostic test. The reliability of a diagnostic test is its ability to reproduce its findings and to provide

consistent results on repeated applications to the same unchanged subject. Reliability needs: 1) overall agreement with the gold standard (angiography - Doppler correlation curve 2) unbiased interpretation (intra - and inter-observer variation 3) reproducibility - consistency and precision (intra-observer reliability). The overall accuracy of the continuous-wave Doppler is 90% for lesions greater than 50% stenosis, with a sensitivity of 87-89% and specificity of 92-99%9.

ACCURACY OF B-MODE IMAGING

High-resolution real-time B-mode imaging is a unique non-invasive technique that images the atherosclerotic plaque and its surface much better than is possible by angiography. Although the angiogram has long been considered the gold standard, this is now challenged especially with the recently developed color-flow Doppler imaging. An international consensus to determine criteria for the quantification of atheromatous stenosis in the extracranial internal carotid artery was published in 1995[10] . Today, new criteria, developed by several teams, are available that are more relevant to modern clinical endpoints[11-17]. Velocity criteria may be inaccurate in a number of clinical conditions[18]. Cardiac arrhythmia, aortic valve insufficiency, tandem plaques, recent hemispheric stroke, carotid dilatation, or aneurysm may result in underestimation of the degree of stenosis. Conversely, carotid coiling or kinking, arteriovenous malformations, carotid body tumors, and contralateral severe stenosis or occlusion may promote overestimation of the luminal narrowing. The residual lumen can also be determined in transverse section for the majority of lesions producing higher grades of stenosis, both in black and white and color modes. Three studies[19-21] performed since 1992 have produced sensitivities/specificities in the range of 85%/97% and 87%/89%, as well as high interobserver correlations (r = 0.83) when compared with angiography.

The differentiation between 99% stenosis and occlusion remains a problem.

Often, in the presence of a 99% stenosis, there is not enough volume flow (energy) to register color, so a careful search for high velocities should be made in the internal carotid artery for at least 1.5 cm from its origin. False positives may arise from small collaterals, and, in our experience, the finding of an occlusion or a 99% stenosis in a symptomatic patient is an indication for angiography. Preliminary results suggest that ultrasonic enhancement agents are likely to provide a solution to this problems[22]. There is also a new modality, power Doppler, that functions independent of the angle of insonation; it provides an outline of the lumen similar to angiography. Both of these techniques require further evaluation in large series.

At the moment, it appears that combining velocity criteria with a high-quality visualization of the stenotic channel in B-mode (black and white), color Doppler, or power Doppler offers the best method to ensure accuracy.

However, further prospective studies are required to determine which combinations would be the most accurate for identifying the defined grades of stenosis upon which therapeutic decision can be based.

IMAGING THE CEREBRAL CIRCULATION

In practice, imaging the cerebral circulation must be very carefully directed to answer the relevant clinical question, and the answer must be likely to influence the patient s management.

The main indications for imaging the cerebral circulation are as follows:

1. The patient is a potential candidate for carotid surgery.
2. Frequent vertebrobasilar TIAs, particularly when subclavian steal is suspected.
3. Possibility of traumatic arterial dissection.
4. Young patient under selected circumstances.

SELECTION FOR CAROTID SURGERY

Evaluating carotid artery disease has become particularly important in light of published reports from the North American Symptomatic Carotid Endarterectomy Trial (NASCET)[23], the European Carotid Surgery Trial (ECST)[24], The Veteran Affairs asymptomatic carotid endarterectomy study[25] and the Asymptomatic Carotid Stenosis Study (ACAS)[26] . NASCET and ECST showed that carotid endarterectomy significantly reduced the risk of stroke in symptomatic patients with 70-99% angiographically defined stenosis of the internal carotid artery. Although the results of the asymptomatic trials are still debatable,[27,28] they claimed that surgery for patients with greater that 60% stenosis is beneficial. There is no doubt that precision of evaluation of the degree of carotid arterial stenosis is of major importance, the degree of stenosis still remains the preeminent prognostic variable in assessing benefit of carotid surgery. It is certain that this will apply as importantly to the patients with asymptomatic as to those with symptomatic disease.

The ideal will have been achieved when harmless investigations can provide, without equivocation, the outlook for patients with precise degrees of stenosis and when this information can be linked to positive scientifically acquired data regarding the results of medical or surgical

therapy. The role of ultrasound as an accurate tool in reliably measuring the degree of carotid stenosis and replacing angiography for selection of patients for surgery is still controversial[29,30].

Several studies have been published showing that carotid endarterectomy can be done without the use of angiography and with acceptable results[31-35].

However, there are certain caveats that must be raised when this issue is discussed. These are as follows:

1. The laboratory must be experienced.
2. The results compared with angiography must be a part of the quality control program.
3. All cases where there is some question of the findings must be subjected to an imaging technique such as angiography, be it standard contrast, spiral computed tomography, or magnetic resonance angiography.
4. Those cases where some serious doubt remains include the following: (a) suggested total occlusion where it is difficult to ascertain the presence of a tight stenosis, (b) lesions not confined to the bulb, (c) tortuous vessels that can make examination very difficult, and (d) extensive calcification making Doppler interrogation impossible.

In our own experience such strategy has been adopted successfully with acceptable results[35].

SCREENING FOR PATIENTS WITH ASYMPTOMATIC CAROTID STENOSIS

In spite of the published results, the answer to the question whether medical or surgical therapy, or a combination of both, can prevent strokes in patients with asymptomatic carotid disease is still controversial. However, the available data suggest that patients with carotid artery stenosis are at an increased risk for subsequent stroke, and even more for non-fatal and fatal myocardial infarction[36,37].

Cardiac and cerebral ischemic risk are closely interrelated and cardiac risks and vascular deaths increase proportionally to the severity of carotid stenosis. In persons with asymptomatic carotid stenosis > 75%, the risk of vascular death from all causes is 6.5% annually[37]. This raises the important question whether screening the population for asymptomatic carotid disease is justified. Is it cost-effective? If it is, who should be screened? How should screening be done?

The goal of screening is to identify the patients who are at risk for stroke and myocardial infarction in order to modify the natural history of the disease either by education (control of risk factors), medical care if available (i.e. antiplatelet drugs), or where justifiable, to select patients for carotid surgery.

Currently, two methods are used to detect potential carotid artery stenosis:

Clinical auscultation for neck bruits and non-invasive studies of the artery.

Cervical auscultation should be included in the physical examination of every patient, especially patients with known vascular risk factors. However, although the auscultation of neck bruits is recommended[38] and non-invasive duplex can confirm the presence of significant obstructive lesions, this is of limited clinical value if it can not be followed by an intervention, either medical or surgical, that prevents subsequent vascular events (i.e. strokes and myocardial infarctions). Until evidence regarding carotid endarterectomy becomes more substantial, the effectiveness of screening for carotid artery disease to prevent subsequent stroke remains in question.

The Canadian Task Force, and recently the Canadian Stroke Consortium[39-40] have argued against routine screening, whereas others have recommended a baseline non-invasive study of carotid arteries in patients considered at high risk for extracranial carotid disease[38-41]. The estimated cost of performing duplex on all Americans with neck bruits is $200 million and the cost of subsequent carotid endarterectomy also needs to be considered. A cost-effectiveness study is needed in order to solve this burning question. However, when cost-effectiveness is calculated, one should bear in mind that detecting carotid artery disease can prevent many myocardial infarctions and other vascular death, and that about one-fifth of those "asymptomatic" patients have silent brain infarction that subsequently can lead to vascular dementia or disabling stroke.

SUBCLAVIAN STEAL SYNDROME

Transient recurrent attacks of focal brainstem dysfunction in the elderly are usually attributed to ischemia in the posterior circulation. Of the various etiological mechanisms postulated, probably the most appealing is that of retrograde flow in the vertebral artery ipsilateral to severe subclavian stenosis that siphons blood from the basilar artery to supply the vascular demands of the exercising arm, thereby causing brainstem ischemia[42].

Evidence from carotid and transcranial Doppler evaluation of patients with unequivocal reversed vertebral blood flow suggests a reexamination of this hypothesis.

In 1961 Reivich and colleagues[43] described two patients with a lesion of the proximal left subclavian or innominate artery causing reversed blood flow in the ipsilateral vertebral artery. Blood siphoning from one vertebral into the other was said to "steal" blood from the basilar artery, and

Fisher named the syndrome "subclavian steal"[44]. All reports were anecdotal, accompanied by radiographic evidence of appropriately reversed blood flow.

The putative symptoms of the subclavian steal syndrome are coolness, weakness, and pain on use of the ipsilateral arm, sometimes accompanied by dizziness. The most serious consequence proposed is transient brainstem ischemia or stroke, either spontaneously or secondary to arm exercise. The clinical signs of occlusive disease of the subclavian artery consist of a diminished pulse in the affected limb with blood pressure reduced by at least 20 mm Hg, and sometimes a supraclavicular bruit is heard[45].

Vascular evaluation by continuous-wave Doppler reliably detects both severe subclavian stenosis and the subclavian steal test are phenomenon[46,47]. The indications for the subclavian steal test by Doppler are[48]:

1. A 20 mm Hg (or more) blood pressure difference between the arms
2. A monophasic waveform from the subclavian artery, including severe stenosis
3. Bidirectional or reversed flow in the vertebral artery while the patient is resting

The subclavian steal test consists of carotid Doppler examination performed with the patient at rest and with a blood pressure cuff around the arm ipsilateral to the subclavian stenosis. The cuff is inflated above systolic pressure for 3 min., the patient exercises the arm for 2 min., and the cuff is quickly deflated. The test is positive if vertebral flow reverses.

Transcranial Doppler ultrasound, a pulsed Doppler technique using a probe with low-emission frequency (2 mHz), allows evaluation of the intracranial posterior circulation[49]. The occipital foramen serves as an ultrasound "window" to examine the distal vertebral artery and the basilar artery and to detect stenosis or changes in flow direction in them.

There is now substantial evidence from angiographic phenomenon and Doppler data of blood flow down the vertebral artery that the "steal" phenomenon is found in 2-9% of patients with generalized atherosclerosis. However, it is merely a benign hemodynamic phenomenon[50].

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