Maltese Medical Journal, 1996; 8 (2): 21-25

Carotid Artery Disease Screening: Assessment of criteria

A Zammit*, A Galea Debono**, A Gatt*

ABSTRACT: The Department of Radiology at St. Luke's Hospital has provided a screening service for stroke related disease since April 1991. This consisted of Duplex Ultrasound screening (DUS) for Extracranial Carotid Artery Disease (ECAD) followed by angiography or intra-arterial digital subtraction angiography (IADSA) or digital intravenous angiography (DIVA) if ultrasound screening was positive for significant disease. The aim of this study was to evaluate in the local context, the various criteria for assessment already established overseas and to devise the best combination of these criteria to improve the detection of disease, thus improving the quality of the local screening service. 504 patients have been screened for stroke related disease. Twelve patients (6M:6F) with significant disease, who were considered for surgery, were referred for angiography, IADSA or DIVA. Comparison of these two modalities, DUS and vascular study, were made on 22 sides for the Multicentre Criteria (MCC), the Modified Seattle Criteria (MSC) and the Modified Washington Criteria (MWC). The accuracy, sensitivity, specificity, positive predictive value and negative predictive value were calculated for the MCC, the MSC and the MWC for peak systolic velocity. For the MCC the end diastolic velocity, the systolic velocity ratio and the diastolic velocity ratio were also compiled. The highest precision for extracranial carotid artery disease screening can be achieved by a combination of the MCC or MSC for peak systolic velocity and with the systolic velocity ratio for the MCC.

* Department of Radiology, St Luke's Hospital, Guardamangia, Malta.
** Department of Medical Neurology, St Luke's Hospital, Guardamangia, Malta.

Correspondence: Dr A. Zammit, Department of Radiology, St Luke's Hospital, Guardamangia, Malta.

Key words: carotid artery disease, Duplex US, angiography, digital subtraction.

This article is based on a paper read at the Third Maltese Medical School Conference, 29th November - 2nd December 1995.

Introduction

Stroke is a common cause of death and it may cause marked disability in the survivors. It is caused by internal carotid artery atherosclerotic stenosis or occlusion in about 30%. Some of these patients have lesions that do well after surgery (endarterectomy). The beneficial effects of surgery are being appreciated now that the mortality and morbidity are low due to operator experience and the right selection of patients. This has been documented by the North American symptomatic carotid endarterectomy trial [1] and the European Carotid Surgery trial [2]. Some of the risk factors for stroke are diabetes, hypertension, increased serum lipoprotein and smoking. Adequate screening can pick up carotid artery disease, thus preventing stroke by treating medically or surgically. Surgery is indicated if the patient is symptomatic or if the stenosis is critical (>80%). In some centres carotid angioplasty or intra-arterial stent are also being carried out. In half of the patients with hemispheric symptoms one finds less than 60% luminal diameter stenosis. This is non-significant stenosis (conventionally, significant stenosis is taken as >60% stenosis, however, others regard >50% stenosis as significant). The non-significant group is treated medically. Carotid artery disease is prevalent in the over 50 age group and in 100 autopsies carried out in over 50 year olds, all had carotid artery disease [3].

The current screening modalities for CAD are Duplex US and Colour Doppler/ Velocity Imaging. These two modalities are much better for picking up disease than Continuous Wave Doppler. Colour Doppler US is highly accurate (92-96%) for disease. US screening is less accurate for mild disease (less than 30% stenosis). The advantages of Colour US Imaging over Duplex US are that the examination is faster and colour imaging helps in identifying narrowed segments and uncalcified plaques. It does not, however quantify the degree of stenosis which is still dependent on Spectral Doppler Analysis. Moreover, colour US is also essential for vertebral artery interrogation. Angiography is the Gold Standard for comparing with Duplex US. Digital intravenous angiography (DIVA) is also a method of examination which reduces the invasive nature of angiography. However, only 73% of these investigations are diagnostically adequate[4-6]. The limitations of DIVA include swallowing reflex artefacts in response to a contrast bolus injection, the large amounts of contrast injections that are utilised for this procedure (35-60ml/ run), the resulting subtraction of pathology such as calcification and the superimposition of all the neck arteries and veins. In the future, Magnetic Resonance Angiography may play a significant role in the non-invasive investigation of the extracranial carotid and vertebral circulation as this new technique is very promising in this respect. A significant stenosis at the internal carotid artery may present with cervical bruits. However, 12% of the general population have a cervical

bruit and only a third of these bruits truly arise from the carotid bifurcation[7]. Thus one cannot rely on bruits for the detection of carotid artery disease as the prognostic significance of a carotid bruit is highly non-specific. Only 13% of carotid bruits have a significant stenosis[8]. Cervical bruits can arise from the internal carotid artery, the external carotid artery, the subclavian artery and can also be transmitted cardiac murmurs. Bruits are present in more than half of carotid stenoses and are classically detected at 50% and over carotid stenosis. Paradoxically bruits disappear at 85% stenosis and no bruit is heard in occlusion. This makes patients in whom detection of asymptomatic stenosis is more desirable the most difficult to identify. A significant stenosis occurs when the luminal diameter is reduced by 60%. This is equal to a cross-sectional area reduction of 70% or more. A critical stenosis occurs when the luminal diameter is reduced by 80%. A critical stenosis carries a high risk of cerebral infarction and is now treated by surgical endarterectomy. Occlusion is also treated surgically if recent in origin. Recent studies also show that atheroma progresses if left untreated. Thus 80% stenosis may progress to ipsilateral occlusion in 35% of patients at six months and in 46% at 12 months. Two thirds of patients progress relentlessly with time[9]. Carotid artery disease is interrelated to both coronary artery disease[10] and to peripheral artery disease[11]. It is very important to screen for carotid artery disease in patients with a history of peripheral or coronary artery disease. In CABG patients, 18% may have significant carotid artery disease. Therefore, prior to CABG the patient should be screened for carotid artery disease. It is necessary to assess the type of plaque present during ultrasound imaging since plaque characterisation is regarded as important for defining patient therapy.

The aim of this study was to evaluate the various criteria for assessment already established namely the Multicentre Criteria (MCC) [12], the Modified Seattle Criteria (MSC) and the Modified Washington Criteria (MWC) [13] and to devise the best combination of these criteria to improve the detection of disease, thus improving the quality of the local screening service.

Patients and Methods

Our screening programme was started in April 1991. 504 patients were screened (M3:F2) with ages ranging from 32 to 80 years (mean age: 56 years). Duplex US was exclusively used in all patients. Figure 1 shows the distribution of the referred patients with gender and age decade. The commonest age at referral was between 61 and 70 years (seventh decade). The indications for carotid artery disease screening which are acceptable for referral include a history of stroke, transient ischaemic attacks, bruits, amaurosis fugax, retinal emboli, follow up after surgery, coronary artery disease, peripheral artery disease and prior to coronary artery bypass grafts. Duplex US scans were routinely carried out with ATL equipment at 5 MegaHertz frequency using a 50 Hertz filter and sampling at a low gate width (1.5 to 3 mm) and an insonation angle of 60 degrees. Ultrasound Imaging was carried out with a Linear Array 7.5 MegaHertz transducer. Duplex US was compared to angiography from 22 samples from 12 patients with an equal gender distribution (M6:F6 ratio). Selective carotid

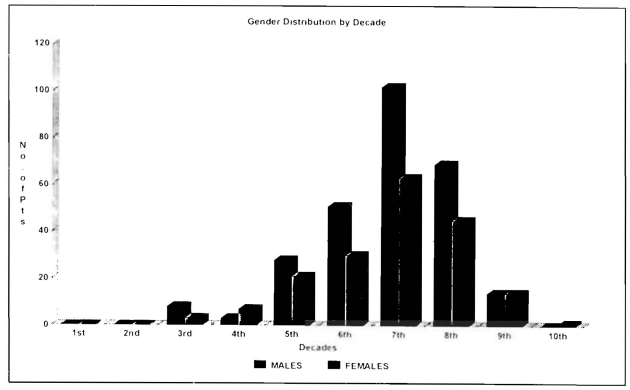

Fig. 1 - Gender distribution by decade.

angiography, digital subtraction angiography (DSA) and digital intravenous angiography (DIVA) were all carried out. Our preference was for DIVA in investigating out-patients, while in-patients were normally subjected to intra-arterial digital subtraction angiography rather than angiography thereby reducing the concentration of the injected contrast medium. Biplane imaging was carried out and stenoses were averaged. Two oblique projections (45° RAO/LAO) were utilised for DIVA, while for IADSA the AP and lateral projections were employed. Preliminary investigations for intra-arterial DSA and angiography necessitated a coagulation profile besides other routine investigations that are normally done, while no such examinations were required with DIVA unless the patients' condition warranted it, such as, where anticoagulant therapy was instituted for the patient's previous condition.

We calculated the following parameters of sensitivity, specificity, positive predictive value and negative predictive value. Doppler spectra were taken from the internal carotid artery and the common carotid artery. We measured the peak systolic velocity (PSV) and the end diastolic velocity (EDV) in these two arteries and investigated also the external carotid artery. The systolic velocity ratio (SVR) and diastolic velocity ratio (DVR) were calculated by dividing the value of the systolic and diastolic velocities respectively from the internal carotid artery by the value in the common carotid artery (Table 1). Plaque characterisation was also noted. More echogenic plaque composition contains a higher collagen content. Hyperechoic plaque with acoustic shadowing was noted in calcified plaque while fibrofatty plaque is homogenous and least echogenic. Hypoechoic plaque with echogenic area/s was identified as intraplaque haemorrhage which is very symptomatic. US Imaging diagnosis is difficult to make with irregular plaque surface and ulcerative plaque while both these entities are risky particularly the latter. In stenosis, flow velocity is inversely proportional to arterial lumen cross-sectional area. If the lumen is stenosed then the velocity increases. If the PSV from the ICA divided by the PSV from the CCA is greater than 1.8, stenosis is significant, implying greater than 60% luminal diameter reduction. The grading of disease severity from our patient group was compared to three criteria: The MCC (Table2), the MSC (Table 3) and the MWC (Table 4). Significant stenosis is 60% with the MCC and 50% with the other centre criteria. A positive test was regarded as a stenosis equal

Table 1 - Doppler flow characteristics in 12 patients with carotid artery stenosis.

Patient number	Side	Angio-graphic stenosis	PSV cm/s	EDV cm/s	SVR	DVR
1	Right	75%	254	101	5.4	6.2
1	Left	66%	203	43	6.0	6.2
2	Right	43%	122	20	1.8	4.0
2	Left	33%	113	15	2.8	2.1
3	Right	20%	96	17	2.8	2.8
4	Left	25%	90	43	1.3	1.2
5	Right	20%	61	21	1.1	1.1
5	Left	30%	72	24	1.0	0.9
6	Right	33%	71	10	1.5	0.9
6	Left	33%	50	20	1.0	1.4
7	Right	25%	76	37	1.2	2.0
7	Left	28%	46	16	0.9	0.6
8	Right	43%	92	22	0.7	0.6
8	Left	100%	110	23	2.1	1.7
9	Right	33%	130	9	1.8	1.3
9	Left	0%	41	14	0.8	0.7
10	Right	60%	121	38	2.0	2.7
10	Left	0%	75	28	1.5	2.5
11	Right	60%	118	17	1.9	1.9
11	Left	90%	176	10	4.0	2.3
12	Right	65%	99	21	1.6	0.6
12	Left	95%	160	21	4.8	1.0

to or above this. The Doppler parameters studied were peak systolic velocity for the MCC, the MSC, the MWC, the end diastolic velocity for the MCC, the systolic velocity ratio and the diastolic velocity ratio for the MCC. The differences between these criteria at the significant stenosis level is a PSV > 130 cm/s with the MCC and the MWC, and a PSV > 120cm/s with the MSC. In the MSC and MWC, filling of the spectral window below the systolic wave is also taken into account. For MCC, significant disease is present also when EDV >40cm/s, SVR > 1.8 and DVR > 2.4. None of these patients had arrythmia, aortic incompetence or other heart conditions which would have interfered with the quantification of stenosis due to non-uniform Duplex US spectra.

Table 2 - Grading Disease Severity, Multicentre Criteria. (NA = not applicable).

	Peak Systolic Velocity	Peak Diastolic Velocity	Systolic Velocity Ratio	Diastolic Velocity Ratio
Normal - mild stenosis (0-39%)	<110	<40	<1.8	<2.4
Mild stenosis (40-59%)	110-130	40	<1.8	<2.4
Significant stenosis (60-79%)	>130	<100	>1.8	>2.4
Critical stenosis (80-99%)	>250	>100	>3.7	>5.5
Occlusion (100%)	0	0	NA	NA

Table 3 - Grading disease severity, Modified Seattle Criteria.

Grade of Stenosis	Spectrum	Peak Systolic Velocity cm/s
Normal	Narrow	< 120
<10%	Broad in deceleration phase	< 120
10-49%	Broad throughout systole	< 120
50-99%	Broad throughout systole	> 120
Occlusion	No signal or low frequency	> - 30

Table 4 - Grading disease severity, Modified Washington Criteria.

Grade of Stenosis	Spectrum	Peak Systolic Velocity cm/s
0-30%	Narrow	<120
31-50%	50-67% filling of window	120-130
51-90%	>67% filling of window	>130
91-99%	window completely filled in	>150
>95-99%	window completely filled in	waveform distorted
Occlusion	No wave form	0

Results

Table 5 depicts the sensitivity, specificity, accuracy, positive predictive value and negative predictive value for the three criteria assessed, namely the MCC, the MSC and the MWC. Taking these parameters in order, the highest sensitivity of 87% was noted using the systolic velocity ratio with the MCC. The maximal specificity of 100% was obtained utilising the peak systolic velocity with all three criteria, namely the MCC, the MSC and the MWC and utilising the end diastolic velocity with the MCC. The MCC and the MSC demonstrated the highest accuracy of 86% when the peak systolic velocity was utilised as a criterion. The positive predictive value was maximal at 100% with four criteria, namely the peak systolic velocity with the MCC, MSC and MWC and end diastolic velocity with the MCC. The highest negative predictive value of 92% was obtained utilising the systolic velocity ratio with the MCC.

For disease in the internal carotid artery the local screening program using Duplex US has an accuracy of 68%, a sensitivity of 50%, a specificity of 83%, a positive predictive value of 71% and a negative predictive value of 67%. From the 22 samples taken

Table 5 - Sensitivity, specificity, accuracy, PPV and NPV for the three criteria MCC, MSC and MWC

	MCC PSV	MSC PSV	MWC PSV	MCC EDV
Sensitivity	70	66	50	25
Specificity	100	100	100	100
Accuracy	86	86	82	74
PPV	100	100	100	100
NPV	80	81	79	71

Positive predictive value	PPV
Negative predictive value	NPV
Peak systolic velocity	PSV
End diastolic velocity	EDV
Systolic velocity ratio	SVR
Diastolic velocity ratio	DVR
Multicentre criteria	MCC
Modified Seattle criteria	MSC
Modified Washington criteria	MWC

there were 15 true positives, 2 false positives and 5 false negatives when compared to angiography/IADSA/DIVA. In the false positives, a 43% carotid stenosis on angiography was picked up as disease of significance and a normal internal carotid artery was mistaken for the external carotid artery which had a 66% stenosis. The reasons for the false negatives were the following: in two cases with a normal internal carotid artery origin, angiography picked up lesions high up in the internal carotid artery, while in another two borderline lesions (50% and 58% stenosis), Duplex US detected them as normal and in another an occluded internal carotid artery was missed for the external carotid artery(which was 57% stenotic) on Duplex US. Currently, surgery is only considered if a critical stenosis or a recent occlusion is confirmed by angiography/IADSA/DIVA in a patient fit for operation and where the future risk of developing a further ischaemic attack is high.

The diagnostic information extracted by utilising Duplex US is quite comprehensive. One can grade stenosis by analysing the spectrum sampled from the internal carotid artery and the common carotid artery. This is important from both the diagnostic and prognostic points of view and is utilised in planning the patient's management. With Duplex US one can diagnose calcified plaque with a high accuracy and this is very important for the surgeon to appreciate prior to endarterectomy, as it will elucidate difficulties he may encounter during surgery. Intraplaque haemorrhage is also being recognised and the accuracy is quoted at 82-90%. However in our experience the accuracy for this was not as high. It is important to recognise this entity as intraplaque haemorrhage is symptomatic and if marked has a poor prognostic significance. Ulcerative plaque is more difficult to diagnose and the accuracy of this entity ranges from 41 to 77%. In this series ulcerative plaque was diagnosed mainly on angiography rather than on US imaging because insufficient importance was devoted to plaque characterisation. Plaque with irregular surface should also be identified. This together with ulcerative plaque may form a nidus for platelet aggregation and thrombus formation. Consequently, this is a potential source of embolisation to the intracerebral circulation.

Discussion

The protocol for treatment of carotid artery disease by disease grade utilised by the study was the following:

- a normal carotid artery, mild carotid stenosis and moderate stenosis were all treated medically
- significant stenoses were usually treated medically, although, in some centres these lesions are being treated by angioplasty.
- critical stenosis, recent occlusions and ulcerative plaque were treated surgically.

Stenosis should be graded and the best accuracy is obtained by measuring the peak systolic velocity utilising the Multicentre and the Modified Seattle Criteria. The best specificity and positive predictive value were obtained by measuring the peak systolic velocity by the Multicentre Criteria and the Modified Seattle Criteria. The best sensitivity and negative predictive value were obtained by measuring the systolic velocity ratio by utilising the Multicentre Criteria. When one sums up these data the common factor in these combinations is found to be the measurement of the peak systolic velocity and the systolic velocity ratio with the Multicentre Criteria and this is recommended for future use in Duplex US screening for carotid artery disease. One of the limitations of this series is that only 12 patients had vascular assessment out of 504 patients screened.

Conclusion

To summarise, we have learnt a few lessons from the start of this screening program. We recommend tapping on temporal artery to identify the external carotid artery. We have also encountered lesions not just at the origin of the internal carotid artery but throughout its whole extent and therefore would recommend investigation of all the regions of the internal carotid artery. It is also important to investigate the external carotid artery as this may also be diseased and can be the source of a bruit. One of our patients who presented with a harsh bruit had an occluded internal carotid artery and a markedly stenotic external carotid artery when we expected to find a stenosis in the internal carotid artery. If the peak systolic velocity sampled from an internal carotid artery is greater than 99cms/s, then this raises suspicion of disease. Imaging of atheroma for characterisation is also important. Plaque should be imaged and described as smooth or irregular, homogenous or heterogenous. The attention to spectral broadening is not necessary if the Multicentre Criteria are being utilised. Finally one should investigate the vertebral artery for subclavian steal as this is associated with cerebral symptoms and thus is important to recognise.

References

1. NASCET: Beneficial effects of the carotid endarterectomy in symptomatic patients with high grade carotid stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. N Engl J Med 1991; 325: 445.
2. ECST: MRC European Carotid Surgery Trial: Interim results for symptomatic patients with severe(70-90%) or

with mild(0-29%) carotid stenosis. European Carotid Surgery Trialists' Collaborative Group. Lancet 1991; 337: 1235.
3. Martin MJ, Whisnant JP, Sayre GP. Occlusive vascular disease in the extracranial cerebral circulation. Arch Neurol 1960; 5: 530-538.
4. Foley WD, Smith DF, Milde MW et al. Intravenous DSA examination of patients with suspected cerebral ischemia. Radiology 1984; 151: 651-659.
5. Hoffman MG, Gomes AS, Pais SO. Limitations in the interpretation of intravenous carotid digital subtraction angiography. A J R 1984; 142: 261-264.
6. Russel JB, Watson TM, Modi JR, Lambeth A, Sumner DS. Digital subtraction angiography for evaluation of extracranial carotid occlusive disease: comparison with conventional arteriography. Surgery 1983; 94: 604-611.
7. Sandok BA, Whisnant JP, Furlan AJ, Mickell JL. Carotid artery bruits: Prevalence survey and differential diagnosis. Mayo Clin Proc 1982; 57: 227-230.
8. Fell G, Breslau P, Knox RA et al. Importance of noninvasive ultrasonic-Doppler testing in the evaluation of patients with asymptomatic carotid bruits. Am Heart J 1981; 102(2): 221-226.
9. Javid H, Ostermiller WE Jr, Hengesh HW et al. Natural history of carotid bifurcation atheroma. Surgery 1970: 67: 80-86.
10. Craven TE, Ryu JE, Espeland MA et al. Evaluation of the association between carotid artery atherosclerosis and coronary artery stenosis. A case-control study. Circulation 1990; 82: 1230.
11. Hertzer NR, Beven EG, Young JR et al. Coronary artery disease in peripheral vascular patients. A classification of 1000 coronary angiograms and results of surgical management. Ann Surg 1984; 199: 233.
12. Bluth EI, Wetzner SM, Stavros AT, et al. Carotid Duplex Sonography: a multicentre recommendation for standardised imaging and Doppler criteria. Radiographics 1988; 8: 487-506.
13. Hartnell GG, Gibson RN, Williams R, Hemingway AP. Carotid artery stenosis - reassessment of the Doppler criteria. EJR 1990; 10: 147-153.