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REVIEW

Joint Recommendations for Reporting Carotid Ultrasound Investigations in the United Kingdom

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Abstract At present in the United Kingdom a number of different criteria are used to grade disease in carotid ultrasound investigations. One main cause of this has been the difference in the method of grading angiograms used in the NASCET and ECST large carotid surgery trials. It is desirable that all centres reporting carotid ultrasound investigations report to the same standard. This paper presents recommendations for the reporting of ultrasound investigations of the extra cranial arteries produced by a Joint Working Group formed between the Vascular Society of Great Britain and Ireland, and the Society for Vascular Technology of Great Britain and Ireland. The recommended criteria are based on the NASCET method of grading carotid bulb disease. Key recommendations include recording peak systolic velocity (PSV) and end-diastolic velocity (EDV) in both internal and distal common carotid arteries; measuring all velocities at a Doppler angle of 45–60°; the use of internal carotid PSV of >1.25 ms^{-1} and >2.3 ms^{-1} and a Peak Systolic Velocity Ratio of >2 and >4 to indicate >50% and >70% stenosis respectively; and the use of the St Mary's Ratio to grade >50% stenoses in deciles. General recommendations are also given for the acquisition, interpretation and reporting of the data.

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Introduction

In the United Kingdom carotid ultrasound is performed by a variety of sonographers, vascular scientists and radiologists, usually reporting their own scans and using reporting criteria that are frequently local to their unit. Such reporting criteria have often been arrived at historically from a number of sources. Those performing carotid ultrasound work in departments ranging from imaging departments in district general hospitals to dedicated vascular laboratories. Patients may then be referred on to specialist stroke and vascular centres with the potential for two different sets of criteria to become confused. Walker and Naylor[1] have recently shown that in some cases practitioners are not sure where the criteria they use come from or how they were derived. Different centres using different criteria to grade carotid disease is a cause of confusion leading to the need for unnecessary repeat testing and is likely to affect the management of patients. The opportunity for appropriate treatment by carotid endarterectomy may be missed or the unnecessary referral of relatively mild disease made if results are being reported to more than one standard. This is clearly unacceptable by the standards of best medical practice using evidence-based criteria. The need for a uniform approach to reporting has also been emphasised by the requirement for service specifications from the Department of Health and in response to the National Strategy for Stroke[2] in which prompt duplex investigation of the carotid arteries is a key factor.

It has been shown that where Duplex ultrasound of the carotid arteries is practised to a well-defined protocol, with attention to detail, by well trained and experienced practitioners, the results obtained compare extremely well with other imaging modalities and a majority of surgeons currently base management decisions on ultrasound without recourse to further imaging.[3,4] More recent recommendations[5] based on a wide-ranging meta-analyses of all imaging strategies for patients presenting with TIA showed that ultrasound was most reliable and cost-effective in determining 70—99% stenosis and less so in confirming 50—69% stenosis. They recommend that for a duplex finding of 70—99% stenosis, or the finding of 50—69% stenosis presenting shortly after onset of symptoms (<4 weeks), confirmatory evidence of a second ultrasound scan (different operator) is sufficient to proceed with surgery. If greater than three months has elapsed then, with a much reduced benefit from surgery, corroborative imaging (contrast enhanced magnetic resonance angiography (CEMRA), computed tomography angiography (CTA), intra-arterial digital subtraction angiography (IADSA)) is needed to ensure a high level of confidence in stratifying the disease. The consistent use of a uniform protocol for stratifying and reporting carotid ultrasound investigations would significantly contribute to the improvement in the methodology used in assessing less invasive imaging tests and give clearer presentation of data and reports of such studies that Wardlaw et al. recommend is necessary.

In an attempt to standardise practice, a Joint Working Group was formed between the Vascular Society of Great Britain and Ireland, representing the diagnostic needs of vascular surgeons, and the Society for Vascular Technology of Great Britain and Ireland, representing the majority of those performing carotid duplex prior to a patient going to surgery. This current report presents the recommendations of that Working Group. In addition to recommending the diagnostic criteria to be used, attention is drawn to a number of issues that affect the accuracy of measurement and hence reliability of the investigation. It is expected that the adoption of these recommendations will lead to a general improvement in performance and uniformity of results of these investigations across all departments. *The recommendations have also received the endorsement of a number of other relevant bodies in United Kingdom listed in* Appendix 1.

Origin of Current Confusion

A number of factors have contributed to the different and confusing range of measurements and values currently being used as diagnostic criteria for carotid duplex ultrasound.

Since 1991 the decision to treat a symptomatic patient who has suffered a TIA or minor stroke has largely been guided by the results of the North American Symptomatic Carotid Endarterectomy Trial (NASCET)[6] and the European Carotid Surgery Trial (ECST).[7] These two trials used angiography as the imaging modality and both showed the benefit of performing CEA in patients with significant internal carotid artery (ICA) disease. NASCET showed a modest but significant benefit in patients with 50—69% stenosis with maximum benefit in patients with 70—99% stenosis. ECST used a different method for calculating the percentage stenosis and produced a similar result but with higher values of modest but significant benefit in patients with 70—79% stenosis with maximum benefit in patients with 80—99% stenosis. Subsequent comparison of the two measurements and re-analysis of the ECST trial data using the measurement method used in NASCET showed that a 50% NASCET stenosis was broadly equivalent to a 70% ECST, while a 70% NASCET stenosis broadly equated to an 85% ECST.[8,9] Not surprisingly, the use of two different methods to calculate degree of stenosis was probably a major source of confusion in deriving valid and reliable duplex ultrasound criteria in the UK.

This confusion was further compounded by the publication of the two asymptomatic trials.[10,11] ACAS used the NASCET measurement method and all patients underwent formal angiography to determine that they had a stenosis in excess of 60%. ACST, however, used ultrasound to determine whether a patient had a stenosis >60%. Accordingly, in current clinical practice, clinicians adopt a number of stenosis thresholds for considering intervention and these can vary quite considerably (and differently) for symptomatic and asymptomatic patients (>50%, >60%, >70%, >80%).

A further source of variation and confusion in the diagnostic criteria used has been the number of different values for velocities and derived indices reported in published studies, and all said to indicate the same percentage stenosis. This in turn has arisen in part from the use of locally derived/validated criteria using different ultrasound scanners and different protocols for factors such as setting the Doppler angle.[12,13] The choice of different cut-off values to give various levels of sensitivity and specificity for screening and decision making has also contributed.[14] In addition to these user based factors, the Working Group was aware that different models of scanner may produce some variation in measured velocities for physical reasons intrinsic to the way an ultrasound scanner works.[15] This last point will be addressed below, under equipment.

The values for the diagnostic parameters given in the recommendations are consensus values that are believed to be concordant with reproducible results across a wide range of machines and reflect the values given in the most reliable studies published.

NASCET vs ECST Methods

Both the NASCET and ECST trials used angiography and calculated the percentage of stenosis as a ratio of diameters measured from the angiogram. The NASCET method compared the diameter of the residual lumen in the stenosis with the diameter of the normal ICA lumen distal to the bulb (Fig. 1). The ECST method compared the residual lumen in the stenosis with an estimate of the diameter of the artery at the point of the stenosis. As the point of maximum stenosis is commonly found within the bulb, the ECST method typically yields a higher value for a stenosis with a given residual lumen than does the NASCET method. Using a regression analysis, Rothwell et al.[8] found the relationship between the ECST and the NASCET values to closely approximate:

$$ECST\% = 0.6NASCET\% + 40\%.$$

This is shown in Fig. 2.

The NASCET method is a more straightforward indicator of the degree to which the ICA is narrowed by the stenosis in that it compares the stenosis to the uniform distal lumen of the artery. It is also more reliably measured from angiograms than the ECST method, where the full diameter of the bulb at the site of stenosis must be estimated.[16] The ECST method gives a better indication of the plaque burden at the site of the stenosis. As an example of the confusion

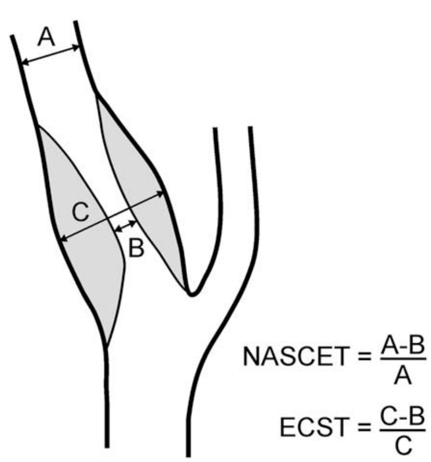


Figure 1 Diagram of stenosis showing the NASCET and ECST methods of calculating percentage diameter stenosis. NASCET used the high distal ICA for measuring distance A.

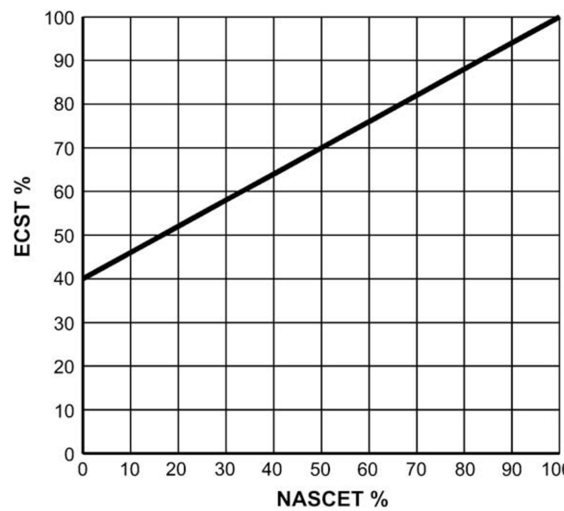


Figure 2 The relationship between percentage diameter stenosis calculated using the ECST and NASCET methods using formula of Rothwell et al.[8]

that may arise in considering the results of a carotid investigation, an ECST 50% stenosis within a carotid bulb may yield 0% using the NASCET method if the residual lumen is no narrower than that of the distal ICA. In the case of mild disease in the wider bulb, the ECST method may even anomalously yield a negative value using the NASCET method. Consistent reporting of lower grade stenoses is a practical issue when surgery is considered for patients with less than 70% NASCET stenosis. Duplex ultrasound has been shown to have good correlation with both NASCET and ECST methods of calculating percentage stenosis and with an appropriate choice of diagnostic criteria each has similar sensitivity and specificity.[14]

Working Group Recommendations

Method of grading

In order to overcome any confusion and to produce uniformity in measurements, it was necessary for the Working Group to take a view on which measurement method to recommend. It is the recommendation of the Group that for all measurements and comparisons the NASCET method should be used. This is the measurement of choice guiding the majority of vascular surgeons working in the UK and provides consistency with what is being used elsewhere.[17,18] In addition, using CT angiography, which is capable of enabling direct millimetre measurements to be made, Bartlett et al.[19] have correlated the NASCET method with residual lumen diameter at the stenosis, and found that a 70% stenosis corresponds to a 1.3 mm residual diameter lumen and a 50% stenosis to a 2.2 mm lumen. This is a measurement that is also accessible to duplex ultrasound.

The large bulb

It is recognized that large plaques in large bulbs but with a good residual lumen may still be a significant risk factor for an embolic event (Fig. 3). This important issue was not addressed when the North American concensus criteria (NACC) were developed.[17] We therefore recommend as an exception, that in the case of a large carotid bulb (e.g.: greater than 10 mm diameter),[20,21] direct measurement of the bulb diameter and plaque thickness is made and reported with a note that there remains a good residual lumen.

Stratifying carotid disease

The basis of stratifying carotid artery disease by duplex ultrasound is accurate measurement of blood velocities together with a qualitative assessment of the appearance of the stenosis including the residual lumen diameter when visualised.[22] It is necessary to assess and compare the arteries on each side in order to account for any collateral flow effects and all carotid examinations should be performed bilaterally and include a basic assessment of the vertebral arteries.

In order to best manage patients and monitor disease progression it is desirable to measure the degree of stenosis in deciles. The use of velocity ratios allows this and is to be recommended. Disease graded as <50% stenosis may be classified as mild disease, with the exception of the large carotid bulb discussed above.

Velocities

We recommend the routine measurement and recording of the peak systolic (PSV) and end-diastolic velocities (EDV) in both the distal common carotid artery (CCA) and in the ICA at the location where the highest PSV is seen. From these four measurements the recommended indices may be calculated and another operator repeating the examination may confirm the findings or detect a variation.

It is known that the PSV measured in the CCA may vary along the length of the artery.[23] The distal CCA measurement should therefore be made within 2 cm of the bifurcation at a point where the vessel still has a uniform diameter, before its widening towards the bifurcation.

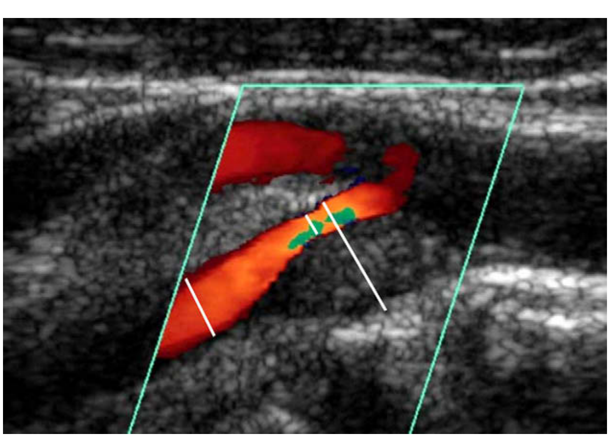


Figure 3 Illustration of a large bulb with a large plaque but a good residual lumen.

The highest PSV in the diseased ICA will be seen at the point of tightest stenosis or in the jet immediately distal to the stenosis. In the normal ICA the highest velocity will be seen distal to the bulb where the artery has a uniform diameter and a ''characteristic'' ICA waveform is seen, and not within the bulb itself, where flow is often disturbed due to vessel geometry and atypical waveforms are seen. All measurements should be made with the vessel imaged in longitudinal section with as long a length as possible shown and with both anterior and posterior vessel walls visualised. This ensures the centre-line velocity is measured and the Doppler angle can be reliably established. The range gate should be set wide enough to ensure that the peak velocity is not missed.[24]

Where there is an irregular heart rate, velocity measurement will be less reliable. Where possible, the velocity should be measured on the second or subsequent cardiac cycle of a string of consecutive regular cycles.

Doppler angle

It has been shown that the value measured for the peak systolic velocity can vary with the Doppler angle used. In general, smaller angles tend to give lower velocities.[25,26] This effect is probably partly due to the effects of the geometry of an ultrasound beam, and partly due to the poorer penetration of ultrasound pulses into a vessel at shallow angles. Further work is needed to evaluate this. Any errors in setting the Doppler angle correction cursor will significantly increase errors in velocity measurements when large angles of insonation are used. It was recognized that the ideal situation would be to measure all velocities at a fixed angle, but that it was not always possible to achieve such a specific alignment either by steering the Doppler beam or by ''heel and toeing'' the probe. Using an angle of 45–60° will minimise these effects and should ensure any error in the velocity measurements due to Doppler angle alignment is less than 10%.

The Working Group recommend that the Doppler angle should be in the range of 45–60° with proper correction/calibration applied using the angle correction cursor.[24] In the case of a tortuous vessel the cursor should be aligned to the tangent of curvature at the point of measurement. In the case of an eccentric jet within a stenosis the angle cursor should be aligned to the jet (Fig. 4).

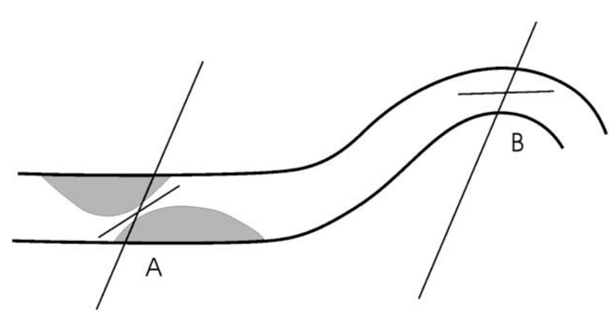


Figure 4 Showing correct alignment for the Doppler angle cursor in the case (A) of an eccentric stenotic jet, and (B) aligning along the tangent of a curved vessel.

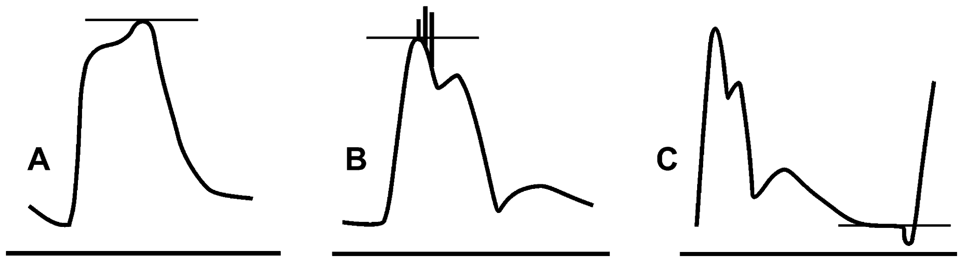


Figure 5 Showing the correct placement of the velocity cursor (A) when the systolic peak is delayed, (B) when there is spike turbulence on the systolic peak, and (C) when the foot of the next systolic peak dips below the end-diastolic velocity.

Velocity cursor placement

In order to make consistent velocity measurements a number of other points should be noted. Fig. 5 shows three cases where the positioning of the velocity cursor should be placed as shown to ensure standardisation of measurements. In the first case, the systolic peak of the waveform is delayed. The maximum value across the whole systolic peak should be used. The second case shows the presence of spike turbulence, for example due to mild proximal disease. In this case the cursor should be placed at the maximum of the underlying systolic peak, not at the top of the turbulent spikes. The third case shows the correct placement of the cursor to measure end-diastolic velocity. Any final small drop in velocity immediately before the foot of the next systolic peak should be ignored.

Doppler gain

A significant source of error is the use of too much or too little gain on the Doppler waveform such that either the display of the waveform is all at peak white or else low volume scattering of the fastest streamline is missed.[27] Fig. 6 shows that this can make a significant difference to the peak velocity measured. The gain should be reduced so that the waveform displayed just reaches peak white at its brightest part, as shown in the centre part of the figure. It is also important to ensure the viewing monitor is correctly set up in brightness and contrast so low level signals are not missed.

Stenosis and distal lumen

In addition to measuring blood velocities around a stenosis, the location of the stenosis and length of long stenoses should be noted. In the case of significant disease, the distance of the stenosis below the angle of the mandible should also be noted to aid any decision to proceed to surgery. Qualitative comments should be made regarding the presence of calcification and irregularity of plaque surface.[28]

The presence or otherwise of a clear distal lumen in the ICA should be reported. In the case of a very tight stenosis or sub-occlusion with trickle flow, there may be significant narrowing of the distal ICA lumen.[8] In these cases the volume flow within the ICA is already severely compromised and the stenosis may even confer protection on further embolic stroke on the side in question and should the operator suspect a sub-occlusion, this needs to be documented on the report so that corroborative imaging (CEMRA, CTA, IADSA) can be performed as appropriate. This type of lesion is now increasingly being treated conservatively.[9,29]

Diagnostic criteria

For the reasons indicated below, the value of the absolute velocity measurement of the PSV in the ICA is subject to many variables and its use as a single measure of the degree of stenosis is less reliable than the use of velocity ratios. Velocity ratios have the advantage of normalising the measurement so that the PSV in the stenosis is judged against the flow conditions pertaining to that particular patient.

The large randomised trials showed that the benefit from operating on stenoses tended to increase with increasing degree of stenosis.[30] In order to enable fully informed clinical decisions to be made regarding the management of patients it is desirable for the degree of

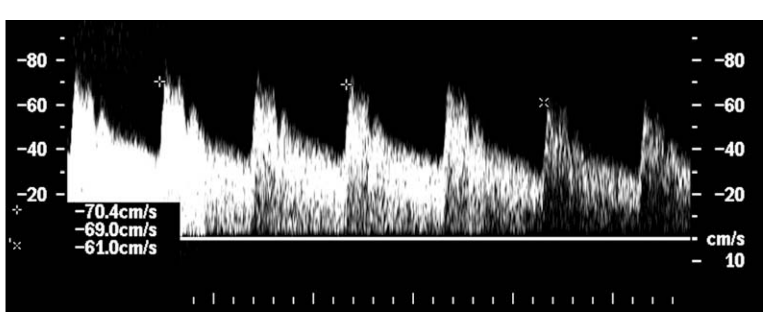


Figure 6 Illustrating the importance of setting the correct gain on the Doppler signal so the waveform shows peak white just at its brightest part, as shown over the middle section.

Table 1 Diagnostic criteria to be applied

Percentage stenosis (NASCET)	Internal carotid peak systolic velocity cm/sec	Peak systolic velocity ratio ICA_{PSV}/CCA_{PSV}	St Mary's ratio[c] ICA_{PSV}/CCA_{EDV}
<50	<125[a]	<2[a]	<8
50–59	>125[a]	2–4[a]	8–10
60–69			11–13
70–79	>230[a]	>4[a]	14–21
80–89			22–29
>90 but less than near occlusion	>400[b]	>5[b]	>30
Near occlusion	High, low – string flow	Variable	Variable
Occlusion	No flow	Not applicable	Not applicable

[a] NACC[17].
[b] Filis et al.[37].
[c] Nicolaides et al.[33].

stenosis to be established within a 10% banding from 50 to 99% stenosis. The St Mary's Ratio[31–34] is believed to be the most robust index enabling grading in deciles to be given and is the ratio recommended by the Working Group.

To summarise, the Working Group recommend the use of the following diagnostic criteria: (a) peak systolic velocity in the internal carotid artery (ICA_{PSV}); (b) peak systolic ICA to peak systolic CCA ratio or Peak Systolic Velocity Ratio (PSVR); and (c) peak systolic ICA to end-diastolic CCA ratio, often referred to as the St Mary's Ratio, with grading in deciles; it is thought that diagnostic confidence is gained where two or more of the measures are in agreement.[33] The recommended diagnostic criteria are tabulated in Table 1.

Peak systolic velocity

ICA peak systolic velocity has historically been the primary diagnostic criteria applied to carotid disease.[32,35,36] We recommend the values given by the NACC[17] of <125 cm/s for <50% stenosis and >230 cm/s for ≥70% stenosis, with an additional value of >400 cm/s for ≥90% stenosis but less than near occlusion.[37] Fig. 7 shows the increase in PSV with increasing percentage diameter stenosis.[38]

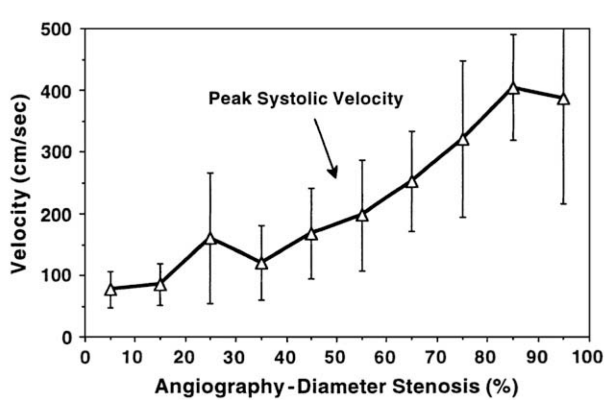


Figure 7 Variation of peak systolic velocity with percentage diameter stenosis (NASCET). Mean values with 1SD error bars shown.[38] (used with permission).

There are a number of potential sources of variability in the internal carotid artery peak systolic velocity. Such factors as:

- variation in the geometry of the bifurcations and the size of bulb[39]
- variation in the vessel size that reflects body size[40]
- collateral flow effects including intracranial/ECA collateral flow[41–43]
- change in ICA flow over the menstrual cycle[44]
- change with age and blood pressure[45]
- the physical parameters of the ultrasound machine[15]

The effect of these factors on blood velocities in diseased vessels is mitigated by the use of velocity ratios. Velocity ratios will also mitigate inter-machine differences.

PSV ratio

The Peak Systolic Velocity Ratio (PSVR), the ratio of the PSV in the ICA to the PSV in the distal CCA, has been widely used and we recommend the values given by the NACC[17] of <2.0 for less than 50% stenosis, >4.0 for ≥70% stenosis with the additional value of >5.0 for ≥90% stenosis but less than

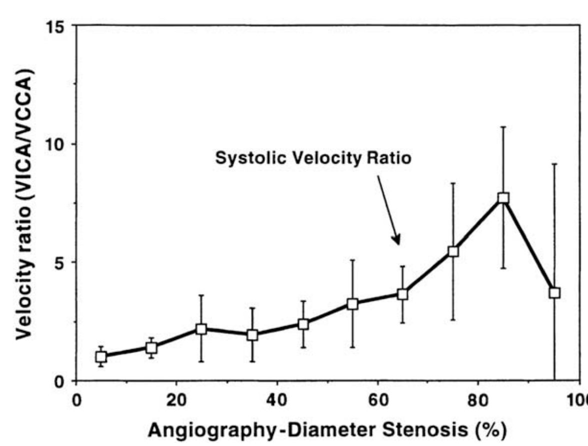


Figure 8 Variation of Peak Systolic Velocity Ratio with percentage diameter stenosis (NASCET). Mean values with 1SD error bars shown.[38] (used with permission).

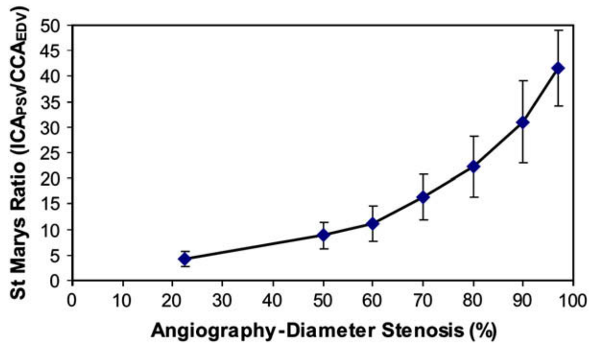


Figure 9 Variation of the St Mary's Ratio with percentage diameter stenosis (NASCET). Mean values with 1SD error bars shown. Data adapted from Dhanjil et al.[34] (data used with permission).

near occlusion.[37] The variation of PSVR with increasing percentage diameter stenosis is shown in Fig. 8.[38]

St Mary's ratio

The St Mary's ratio is formed from the ratio of the PSV in the ICA as the numerator, a value that increases with degree of stenosis, over the EDV in the distal CCA as the denominator, a value that decreases with increasing ICA resistance caused by a progressively severe stenosis.[34] This produces a graph with a wide range of values for the index and sufficiently low data spread so as to allow grading in deciles (Fig. 9). Using ROC analysis the St Mary's Ratio of 14 indicates 70% stenosis with a sensitivity of 0.93 and specificity of 0.93. A ratio of 11 indicates 60% stenosis with a sensitivity of 0.91 and specificity 0.94. Table 1 shows the full set of ratio values for grading in deciles.

Cautions

There are, however, a number of situations in which care must be exercised in interpreting the data and issuing a diagnostic report. Accordingly, it is important that these are clearly ''flagged'' so that corroborative imaging (CEMRA, CTA, IADSA) can be performed as appropriate (Table 2).

1. Where there is bilateral reduction in, or retrograde end-diastolic flow in the CCA there is the possibility of aortic valve disease with regurgitation occurring during the diastolic phase. This will be seen in the CCA end-diastolic velocity even in the absence of severe ICA stenosis.[46] In this situation the St Mary's Ratio should not be used. An example is shown in Fig. 10. Transmitted turbulence on the systolic peak may also be seen.
2. Where there is bilateral reduction in end-diastolic flow throughout the carotid arteries, with the ICA waveform looking more pulsatile, like an ECA waveform, than the normal ICA waveform, there is probably reduced vessel wall compliance due to arteriosclerosis. In this situation the St Mary's Ratio may be less reliable. This waveform type, shown in Fig. 11, is especially seen in very elderly patients. It can lead to overestimation of stenoses.
3. Where there is moderate to severe disease on one side with severe disease in the contralateral side there is a tendency to overestimate the disease on the less severe side as the vessel is acting as a collateral, even though it itself is diseased. [41,42]
4. Unusual or inexplicable waveforms should be noted as they may indicate unusual inflow or outflow problems.
5. Inadequate visualisation for any reason may mean that diagnostic confidence is lost and a full evaluation of any disease is not possible. This should be recorded in the final report.

Table 2 Cautions

• bilateral zero or retrograde end-diastolic flow in CCA —possible aortic valve disease
• bilateral reduction in diastolic flow — arteriosclerosis
• bilateral significant disease — collateral flow effects
• inadequate visualisation
• unusual waveforms

If for any reason the ultrasound scan is considered to be inadequate for a firm diagnosis to be made, or questions remain that cannot be answered by the data collected, the report should note the reason and suggested that further imaging is advisable (CEMA, CTA, IADSA).

Vertebral arteries

Unless vertebro-basilar symptoms are suspected, many departments do not routinely look at the vertebral arteries when performing a carotid duplex ultrasound scan. The Working Group believe that this is a useful addition to the carotid investigation and that a basic examination of the vertebral arteries, including the subclavian arteries if indicated, should be included.[47] This will increase the overall picture of collateral flow and in the case of any abnormality, be an adjunct to determining the management of the patient. A basic examination of the vertebral arteries is to identify the presence of antegrade flow with a normal waveform at or near the level of the carotid bifurcation.[24] Very high flows may indicate a collateral route. Transient or full steal waveforms indicate the need to investigate the ipsilateral subclavian artery. The

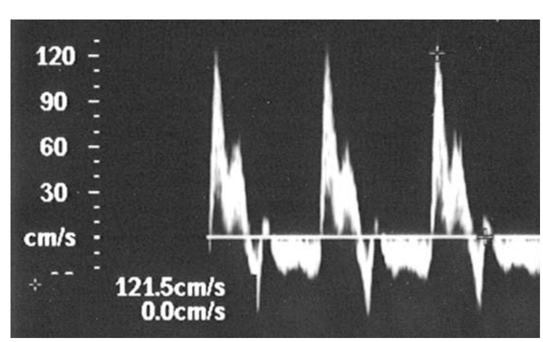


Figure 10 Illustration of CCA retrograde diastolic flow in the presence of aortic valve regurgitation.

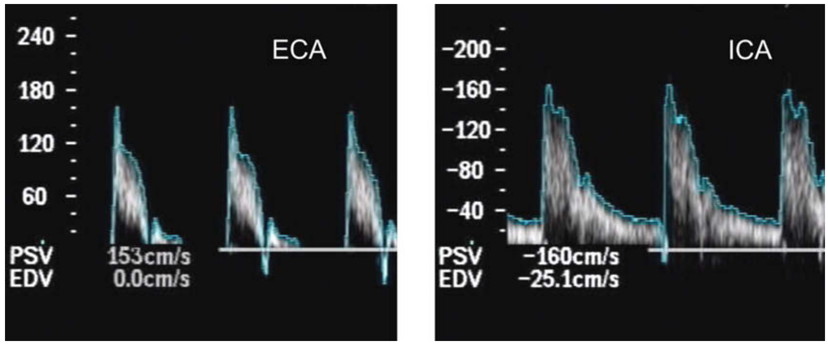


Figure 11 Illustration of waveforms from an elderly subject showing arteriosclerosis. Note the raised peak systolic velocities and reduction in end-diastolic velocity in both ECA and ICA waveforms.

detection of possible proximal subclavian disease is important to document in patients undergoing ultrasound screening of their extra cranial arteries prior to coronary bypass as the internal mammary artery (IMA) is increasingly being used as a bypass conduit. If a significant proximal subclavian stenosis is missed, the patient can develop persisting angina post-operatively due to 'coronary steal syndrome'.

Reporting

The Working Group recommend the use of a pro-forma reporting form that includes an illustrative diagram as shown in Fig. 12. This enables an immediate visual indication of disease severity and location to be seen together with the recommended measurements, indices and diagnostic report.

Scanning equipment

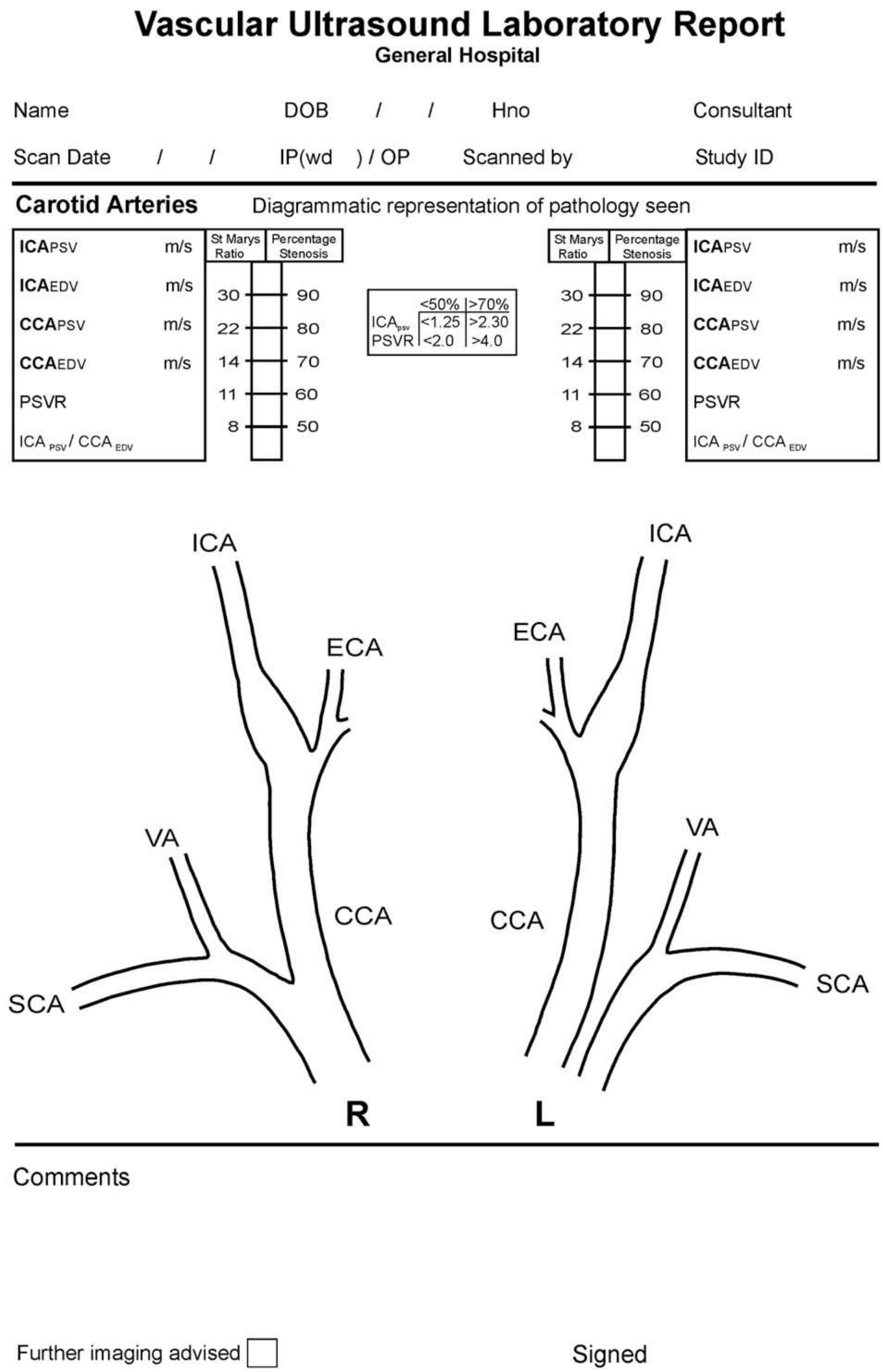
Duplex ultrasound of the carotid and vertebral arteries relies on good quality imaging with sensitive colour and pulsed Doppler modes. Plaques may have low echogenicity and it is important to be able to distinguish subtle grey levels within the B-mode image. Good penetration and contrast resolution is needed for the more difficult patient.[22] Smaller portable equipment may be suitable for performing carotid screening and confirming mild or no disease, but may not meet the high specification needed to categorize more severe stenoses that may warrant intervention. Accordingly, stenoses >50% suspected on "portable" machines should be confirmed and stratified using higher specification equipment.[48]

Over the course of time, the image quality on a scanner may gradually deteriorate, for example through element drop-out on the transducer probe, and the user may not appreciate this.[49] It is also important to know the accuracy of velocity measurements produced by the machine. We therefore recommend that a programme of routine quality assurance for both imaging and Doppler modes on the equipment be instituted, possibly in collaboration with a local medical physics department.[50,51]

One area of concern within the Working Group was the lack of important information from the manufacturers of ultrasound scanners regarding the accuracy of their velocity measurements across the field of view shown by the scanner. Knowledge of the accuracy of velocity measurements is vital when diagnostic decisions are being based on those velocity measurements and it prevents differences in clinical results between manufacturers equipment being easily assessed. This is a surprising omission and compares badly with the emphasis put on the accuracy of caliper and area measurements made on B-mode images. Howard et al.[52] have shown scanning equipment to be a source of measurement differences. The accuracy of the velocity measurement depends on a number of factors.[15] The most common velocity measurement to make is the maximum or peak velocity at some location, as is the case in carotid scanning. This will depend on the Doppler angle assumed within the total beam width of the Doppler beam.[15,53] In general this may vary for different points within the field of view and for different degrees of beam steering. It will also depend on the speed of sound assumed for solving the Doppler equation. Further compensation may be made for intrinsic spectral broadening[53] and sample volume width. It is possible in principle to correct for the differences due to these factors but at present it is not known whether current equipment does this. To do so would improve the reliability of velocity measurements and remove some of the variability we have already noted.

Audit and feedback

Finally, the Working Group recommend the use of audit on performance and reporting.[52,54,55] In particular, to ensure that different individuals obtain consistent results on the same machine and that different machines within a department also give consistent results. A consistent reporting style and vocabulary should be maintained between operators. Such audit should enable inter-observer and inter-departmental problems to be picked up and reviewed, thereby enhancing the reliability of carotid duplex ultrasound. As new information becomes available it may become timely to update these recommendations and the Working Group, through their parent bodies, welcomes feedback on the implementation of these recommendations.



Vascular Ultrasound Laboratory Report

General Hospital

Name DOB / / Hno Consultant

Scan Date / / IP(wd) / OP Scanned by Study ID

Carotid Arteries Diagrammatic representation of pathology seen

ICAPSV	m/s
ICAEDV	m/s
CCAPSV	m/s
CCAEDV	m/s
PSVR	
ICA $_{PSV}$ / CCA $_{EDV}$	

St Marys Ratio	Percentage Stenosis
30	90
22	80
14	70
11	60
8	50

	<50%	>70%
ICA_{psv}	<1.25	>2.30
PSVR	<2.0	>4.0

St Marys Ratio	Percentage Stenosis
30	90
22	80
14	70
11	60
8	50

ICAPSV	m/s
ICAEDV	m/s
CCAPSV	m/s
CCAEDV	m/s
PSVR	
ICA $_{PSV}$ / CCA $_{EDV}$	

Comments

Further imaging advised ☐ Signed

Figure 12 Template of a carotid ultrasound reporting form incorporating the recommendations of the Working Group.

Conclusion

Every imaging modality has its limitations as to when it can be accurately and reliably applied to obtain diagnostic information. With care and attention to detail, ultrasound is a reliable diagnostic tool that has an important role in the cost-effective diagnosis and grading of carotid disease. It is valuable both as a screening tool and as a stand-alone modality to make a decision to proceed to surgery, although it may frequently be supplemented by other imaging. Repeat scans may be made if necessary without hazard to the patient and confirmation of continuing patency immediately prior to surgery assured. The reliability, repeatability and therefore robustness of results across departments requires that everyone is scanning to a similar standard and protocol. The recommendations made here are an attempt to standardise practice across the United Kingdom. They form a minimum set of measurements that the Working Group felt were necessary and it is recognized that some centres will wish to perform additional measurements for their own use, for example, looking at plaque morphology.[56] The recommendations only apply to native carotid vessels and do not cover the diagnostic criteria to be used in investigations post-CEA or within stents.

Recommendations

- Carotid duplex should be a bilateral scan and include a basic assessment of the vertebral arteries.
- All results and calculations to refer to the NASCET method of measurement
- The following four velocities to be measured and recorded:
  PSV and EDV in CCA 1-2 cm below bifurcation
  PSV and EDV in ICA at point of highest velocity, i.e. stenosis jet or ICA distal to bulb in the absence of significant disease
- All velocities to be measured at a Doppler angle of 45–60°, with proper correction/calibration applied using the angle correction cursor
- PSV in ICA and PSVR to stratify 50% and 70% levels (see Table 1)
- St Mary's Ratio to stratify in deciles (see Table 1)
- In the case of a large plaque in a large bulb (>10 mm dia) measure and report the bulb diameter, plaque thickness and residual lumen
- Qualitatively note the nature of the plaque (calcified, irregular, echo-poor, etc.)
- Record length of longer stenoses
- Record distance of bifurcation below mastoid process (cm)
- Record presence or otherwise of clear distal lumen and note size if it is reduced
- Note any cautions in diagnostic reliability of the report

Conflict of Interest/Funding

None declared.

Appendix

List of bodies endorsing these recommendations:

The British Medical Ultrasound Society
The Royal College of Physicians
The Society and College of Radiographers
The Society for Vascular Technology of Great Britain and Ireland
The United Kingdom Association of Sonographers
The Vascular Society of Great Britain and Ireland

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