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A comparison of intra-arterial digital subtraction angiography with doppler sonography in the assessment of carotid arterial stenosis

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SUMMARY

A comparison is made of the use of selective intra-arterial digital subtraction angiography and doppler sonography in the assessment of disease in 206 carotid arteries. Maximal stenoses in each of the internal, external and common carotid arteries were recorded and compared using both modalities. In 93% of cases, arteries reported as normal ultrasonically were also found to be normal on angiography. However, agreement between the modalities in the assessment of severe stenoses was rather less at 79%. Overall agreement between the two modalities was good using statistical analysis (weighted Kappa). It is our view that ultrasound is reliable in normal vessels, but where significant disease is present the rate of error between the two modalities is too high to warrant omission of angiography.

INTRODUCTION

With the advance in ultrasound technology there has been recent speculation that angiography is not always necessary prior to endarterectomy.[1] In this study we compare the maximal stenosis measurements (by area) recorded by intra-arterial digital subtraction angiography (DSA) and doppler sonography in each of the common, internal and external carotid arteries. We also aim to draw conclusions as to the role of each modality in the diagnosis of carotid artery disease.

METHODS

This retrospective study consisted of 103 patients who underwent both selective carotid arteriography and doppler sonography during 1993.

The carotid arteriography was performed in a dedicated angiographic suite using digital subtraction facilities (Polytron-Siemens, Erlangen, Germany). In all cases a 5 French intra-arterial catheter was introduced via a femoral artery and a single 35 degree, left anterior oblique (LAO) view of the aortic arch was obtained to visualise the origins of the great vessels. Using a 5 French headhunter (Cook) or 5 French sidewinder (Cordis) catheter both common carotid origins were selected and images obtained of the common carotid artery, its bifurcation, the internal carotid and the external carotid arteries. Our standard protocol comprised a single lateral projection of each carotid artery with a 35 degree LAO arch projection. However, where necessary, additional 45 degree oblique and posteroanterior (PA) views were obtained. The region of maximum stenosis was identified in each of the common, internal and external carotid arteries and calculations obtained from aboard computer software (Siemens, Erlangen, Germany). In three patients it proved impossible to selectively

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cannulate the left common carotid artery and in these cases stenosis measurements were obtained using the non-selective arch projection to visualise the left bifurcation. All examinations were either performed or supervised by a consultant radiologist.

The doppler sonography examinations were performed using an Ultramark 9 scanner (Advanced Technical Laboratories, California, USA). Each vessel was visualised in the transverse and longitudinal plane, and doppler spectra were obtained. The doppler frequency used was 3 MHz and the pulse repetition frequency (PRF) was 3.8 KHz. The scanning angle used was <68 degrees in all cases. Real time B-scan images were obtained of the common, internal and external carotid arteries and maximal stenosis measurements were inferred from the doppler spectra by Fast Fourier Transformation of data by computer software. No reference to plaque morphology was considered. The examinations were performed by experienced vascular sonographers in a dedicated vascular laboratory setting.

The Kappa statistic was used to assess agreement between the categorisation schemes using sonography and DSA. It has a maximum of one when agreement is perfect, a value of zero indicates no agreement better than chance. Where the categories are ordered it is preferable to give a weight to disagreements according to the magnitude of the discrepancy. Thus in this paper a weighted Kappa statistic has been reported. Values of Kappa in the range 0.4 – 0.6 indicate moderate agreement, 0.61 – 0.80 indicate good agreement and values in the range 0.81 – 1.00 indicate very good agreement.[2]

RESULTS

The results are presented in Tables I - III with the maximum stenosis detected in each vessel placed in groups according to severity.

TABLE I

Common Carotid Artery

		DSA					
	% stenosis	*normal*	*0-15*	*16-40*	*41-70*	*71-99*	*occluded*
ultrasound	normal	104	0	0	0	0	0
	0-15	38	14	1	0	0	0
	16-40	14	3	7	0	0	0
	41-70	5	1	2	8	1	0
	71-99	0	0	0	2	4	1
	OCC	0	0	0	0	0	1

Total = 206 Arteries

Weighted Kappa = 0.579 (95% CI = 0.48, 0.673)

TABLE II

Internal Carotid Artery

		DSA					
	% stenosis	*normal*	*0-15*	*16-40*	*41-70*	*71-99*	*occluded*
ultrasound	normal	62	5	4	2	0	0
	0-15	3	11	1	2	0	0
	16-40	4	3	13	3	<u>2</u>	0
	41-70	0	0	4	14	3	0
	71-99	0	0	3	2	42	<u>6</u>
	OCC	0	<u>1</u>	0	<u>1</u>	0	9

Total = 206 Arteries. 6 not seen on ultrasound

Weighted Kappa = 0.819 (95% CI = 0.770, 0.869)

(underlined = a particularly surprising result)

The figures in Table I show that in the common carotid artery there was reasonable agreement between the two modalities with a weighted Kappa of 0.579 (95% CI = 0.486, 0.673). It is interesting that all 104 cases by ultrasound described as normal were also found to be normal angiographically. However in 47 cases (23%), mild to moderate disease revealed by ultrasound was described as normal on angiography.

Table II demonstrates the results obtained from the internal carotid artery. Again, good agreement between DSA and doppler sonography was obtained with a weighted Kappa of 0.819 (95% CI = 0.770, 0.869). Of 73 cases described as normal by ultrasound 62 were also passed as normal by DSA. None of the remaining 11 cases had severe disease (greater than 70% stenosis angiographically). Perhaps the most important indicators are those that place the patients in a group with severe disease (greater than 70% stenosis) that would suggest endarterectomy as a beneficial procedure for management (in symptomatic cases). Of 47 cases of severe disease detected angiographically, 42 were similarly described on ultrasound. The remaining 5 (or 12%) were placed in a group of lower severity. On the other hand, of 53 cases of severe disease detected on ultrasound, 42 were similarly described on DSA. Six of these patients demonstrated an occlusion on DSA and five were placed in groups of lower severity. Fifteen complete occlusions were reported on DSA of which nine were seen on ultrasound, the remaining six were reported as severe stenoses (70 - 99%). A total of six internal carotid arteries were not seen on ultrasound.

Table III demonstrates the results obtained from the external carotid artery. DSA and ultrasound placed patients in the same group of disease severity in 80% of cases. There was good reciprocity in those patients described as normal: 128 cases reported as normal on angiography compared with 116 cases (or 91%) on ultrasound. There was less close agreement in the detection of occlusion with only two out of 6 occlusions reported on DSA being detected on ultrasound. Overall agreement between the two modalities was good with a weighted Kappa of 0.724 (95% CI = 0.631, 0.818).

DISCUSSION

When taken as a whole intra-arterial digital subtraction angiography (DSA) and ultrasound agree on the severity of stenosis in just over seventy percent of cases and are within one grade of each other in ninety percent of cases. It is more interesting, however, to look at areas where discrepancies occur. One such area is in the detection of mild disease. Colquhoun et al[3] concluded that ultrasound was more sensitive in the detection of mild disease than intravenous digital subtraction angiography; we have found this also to be true of intra-arterial DSA, with 44% of lesions estimated at less than 40% stenosis on ultrasound reported as normal on angiography Ultrasound also reliably detects a normal vessel with 93% of cases reported as normal on ultrasound giving a similar result on DSA. Zierler et al[4] found that a normal doppler sonographic examination predicted a benign clinical outcome without operation, confirming the validity of using ultrasound as a screening procedure to

TABLE III

External Carotid Artery

		DSA			
	% stenosis	*normal*	*0-50*	*51-99*	*occluded*
	normal	116	4	<u>5</u>	<u>1</u>
	0-50	9	21	5	<u>1</u>
ultrasound	51-99	<u>3</u>	3	25	2
	OCC	0	0	0	2

Total = 206 Arteries. 9 not seen on ultrasound
Weighted Kappa = 0.724 (95% CI = 0.631, 0.818)
(underlined = a particularly surprising result)

detect those patients without significant carotid disease.

Of most critical interest are significant stenoses (greater than 70%) particularly of the internal carotid artery. Of 47 severe stenoses reported on DSA, 42 (or 89%) were similarly outlined on ultrasound. Of 53 severe stenoses reported on ultrasound, 42 (or 79%) were also similarly grouped on DSA. Poindexter et al[5] in a study of 238 cases felt that the error rate in this clinically significant group was too high to manage these patients by ultrasound alone. On the other hand Hill et al[1] in a study of 101 patients concluded that a preoperative arteriogram is generally not necessary if a duplex scan is performed.

Farmilo et al have expressed the view that routine angiography is unnecessary in selected patients but that a suspected occlusion should be confirmed by angiography.[6] Our results would support this opinion with a rate of agreement of just over 50% on the finding of occlusion on ultrasound and DSA. However, we conclude that the rate of error in those patients with significant stenoses is also too high to warrant management decisions on the basis of an ultrasound examination alone.

In this study we did not analyse plaque surface morphology. Previous studies have demonstrated that ulceration is more likely to be found in symptomatic patients and that plaque morphology as well as stenosis severity should be considered when deciding management.[7] Steinke et al found a 70 % agreement in detection of plaque ulceration between angiography and ultrasound; however, no haemodynamic patterns successfully predicted those patients who were more likely to be symptomatic.[7] It is clear that ultrasound has a leading role to play in the definition of plaque morphology and its clinical consequences and in this respect it has clear advantage over angiography.

Inadequate visualisation of the internal carotid artery occurred in six cases of this study. Recently work by Meents et al has attempted to address this problem.[8] Twenty-nine cases with insufficient signal intensity, mainly due to dorso-medial origin of the internal carotid artery, were contrast-enhanced with galactose microspheres (SHU 508A, Schering, Berlin). In all cases signal intensity increased and no complications were reported. Galactose microspheres increase the echogenicity of blood by trapping small volumes of air, thus increasing the visibility of vessels.

Recently attention has focused on the comparison of magnetic resonance angiography (MRA) with conventional angiography and duplex scanning. Toh et al described 70% agreement between measurements reported on MRA and those on conventional angiography.[9] Riles et al found reasonable correlation except in the detection of occlusion, where MRA tended to overread angiographically patent vessels as complete occlusions.[10] With the increasing availability of magnetic resonance imaging the technique of MRA of the extracranial carotid vessels will no doubt assume a greater role. However, limitations of cost, availability and safety with regard to metallic surgical clips ensure that doppler sonography and angiography will have a dominant role for some time to come.

In conclusion our results suggest that doppler sonography is extremely reliable in the detection of normal and moderately diseased vessels and is therefore a good first line investigation for patients with suspected carotid disease. Its role in post-operative endarterectomy follow-up is also well described.[11] Ultrasound also has a leading role in the detection of plaque morphology. However, with lesions above 70% stenosis, error rates between the modalities are sufficiently high to require angiography as part of the imaging protocol.

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