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Prospective, Correlative Study of Color Duplex Sonography and Intra-Arterial Angiography in Peripheral Arterial Diseases

KEYWORDS: Color duplex sonography, stenosis, occlusion

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ABSTRACT *Seventy-one patients of suspected peripheral arterial disease were evaluated with Color Duplex Sonography (CDS) and angiography. In 71 patients, total 53 lower limbs in 43 patients and 29 upper limbs in 28 patients were studied with CDS and angiography. Compared to angiography, CDS revealed sensitivity of 83%, specificity of 96%, PPV of 88%, NPV of 94% and accuracy of 92% for detection of various lesions in peripheral arterial disease. The overall sensitivity of 85 and 66%, specificity of 96 and 99% and accuracy of 93 and 98 % was seen with CDS scanning for detection of occlusion and >50% stenosis respectively. CDS is a rapid, non-invasive and relatively accurate modality for identification and localization of various vascular lesions in peripheral arteries. CDS can be used as a screening modality for patients with symptomatic peripheral arterial diseases.*

Introduction

The purpose of noninvasive testing for peripheral arterial disease is to provide objective information that can be combined with the clinical history and physical examination to form the basis for decisions regarding further evaluation and treatment. Contrast arteriography, generally being accepted as "gold standard" for evaluating arterial disease, is invasive, expensive and poorly suited for screening or long term follow up. In addition arteriography provides anatomic rather than physiologic, hemodynamic information and is subject to significant variability at the time of interpretation[1-3]**.** The initial application of duplex scanning concentrated on clinically important problem of extra cranial carotid artery disease. The focal nature of the carotid artery disease and its superficial location contributed to the success of these early studies[4]. First experiences in duplex scanning of aortoiliac and femoropopliteal arteries were published by Jager et al[5]. The agreement between duplex scanning and angiography was proved to be as good as the agreement between two different radiologists evaluating the same angiograms[6]. The purpose of this study was to compare the efficacy Color Duplex sonography (CDS) to peripheral arteriography and to review the accuracy of CDS findings in patients with symptomatic peripheral arterial disease compared with intra-arterial angiography.

Materials and Method

Seventy-one patients, referred for various complaints and pathologies of peripheral arteries, were prospectively evaluated with Color Duplex Sonography (CDS) followed by angiography was used as "gold standard" to compare the results of CDS examination. The scanning combined B-mode ultrasound, color flow imaging and pulsed Doppler spectral evaluation. For deep vessels like abdominal aorta the 3-6 MHz convex transducer was used and examination of superficial arteries was done using high resolution, 6-10 MHz linear transducer. Diagnostic arteriography was performed by means of a Seldinger technique with femoral or brachial artery route. Standard uniplanar angiograms were obtained with oblique or lateral views taken at the discretion of the angiographer.

Stenosis were quantified using peak systolic velocity (PSV) ratio across lesion and comparing it with PSV in the nearest proximal disease free segment. An increase in the peak systolic velocity ratio (PSVR) of >2 was used to define significant (>50 %) stenosis. Color aliasing, marked increase in the systolic velocities with extensive spectral broadening and loss of flow reversal were used as supportive findings for diagnosis of significant stenosis (Fig.1A-C). The absence of flow on color Doppler interrogation was used to denote occlusion (Fig. 2A-C). Swirling color flow within the patent lumen was used to identify the pseudoaneurysm (Fig.3 A,B). To-and-fro (bidirectional) pattern velocity waveform was used to identify the neck of a pseudoaneurysm. Aneurysm was defined as focal enlargement of >20% of the expected vessel diameter. Monophasic tardus parvus waveform with markedly reduced peak velocity in distal arteries was indicative of significant lesion in proximal arterial segments. For the purpose of the data collection and analysis of results the lower and upper limb arteries were divided in following segments. Lower limb - Infrarenal Aorta (IRA), Common Iliac artery (CIA), External Iliac artery (EIA), Common Femoral artery (CFA), Profunda Femoris artery (PF), Proximal, Mid and Distal Superficial Femoral artery (SFA), Proximal and distal Popliteal artery (POP), Tibioperoneal arteries which included Anterior Tibial artery (ATA), Posterior Tibial artery (PTA) and Peroneal artery (PA). Upper limb - Innominate artery, Proximal Middle and Distal Subclavian artery (SCA), Axillary artery (AA), Proximal, Middle and Distal Brachial artery (BA), Radial artery (RA), Ulnar artery (UA).

Results

Total 71 patients of age ranging from 13 to 80 years with M: F ratio of 3.2:1 (male -54, female-17) were included in the study. Total 53 lower limbs in 43 patients and 29 upper limbs in 28 patients were evaluated. The most common presenting clinical manifestation were rest pain (35.35%), followed by tissue loss which included cases of ulcers and gangrenous changes (22.22%) and trauma (21.21%). Distribution of adequate visualization of arterial segments in lower and upper limbs by CDS is given in table 1. Aor-

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toiliac segments and tibioperoneal arteries were most difficult to evaluate, while accurate CDS evaluation of femoropopliteal segments, axillary, brachial and radioulnar arteries was possible in all patients (100 %). Indirect conclusion of normal or diseased (>50% stenosis, occlusion) aorto-iliac segment in 21 limbs and proximal left SCA in 4 cases was drawn by spectral waveform analysis of distal arteries. The various lesions which were detected with CDS and angiography were occlusion (O), >50% stenosis (S), pseudoaneurysms (PA), aneurysm (AN) and arteriovenous fistula (AVF).

Out of total 689 lower limb arterial segments, 629 segments were included in the analysis while 60 segments which were not adequately visualized on CDS were excluded from the analysis. Out of total 276 upper limb arterial segments, 274 segments were included in the analysis. Complete agreement between CDS and angiography was found in 436 normal segments and 140 diseased segments of lower limbs and in 188 normal segments and 67 diseased segments of upper limbs. The maximum sensitivity and specificity of CDS compared to angiography in correct detection of lesion was seen in common femoral artery (100% sensitivity, 100% specificity). The maximum false negative results were seen in tibioperoneal arteries and aortoiliac (13 and 6 respectively out of 33) segments. The CDS could distinguish between normal and diseased segment with overall sensitivity of 81% and 87%, specificity of 96% and 95 % and accuracy of 92% and 93% in lower limb (Table 2) and upper limb (Table 3) arteries respectively.

CDS showed sensitivity of 83%, specificity of 95% and negative predictive value of 95% in indirect detection of significant lesion in proximal segment by studying the distal arterial waveform (Fig. 4). Color flow imaging showed sensitivity of 100%, while spectral Doppler imaging showed sensitivity of 83% in the detection of the pseudoaneurysms and aneurysms. The neck of the pseudoaneurysms could be seen with CDS in 5 out of 6 lesions (83%). We had a single case of traumatic AV fistula which showed perivascular color artifact, high-velocity arterialized waveform in draining vein and turbulent, high-velocity spectral flow spectrum at arterio-venous junction (Fig. 3C). CDS compared to angiography showed overall Sensitivity of 83%, Specificity of 96%, PPV of 88%, NPV of 94% and accuracy of 92% in the diagnosis of various lesions in the peripheral arteries of upper and lower limbs.

Discussion

The CDS showed overall sensitivity of 85%, specificity of 97%, PPV of 90%, NPV of 95% and accuracy of 93% for detection of various lesions in aortoiliac segments. These matches well with the results reported by Legemate DA, Teeuwen C et al[7] who have given overall sensitivity and specificity to detect lesions of greater than or equal to 50% diameter reduction as 84% and 96% and sensitivity of 92% and specificity of 99% for occlusions in aortoiliac segments. Langsfeld M, Nepute J et al[8] and Legemate DA, Teeuwen C et al[8] have reported up to 100% and 96% visualization of aortoiliac segments respectively. However, in the present study, in 32 limbs (60%) aortoiliac segments were completely visualized on CDS and in 21 limbs (40%) indirect conclusion of normal or diseased aortic or aortoiliac segment (occlusion or > 50 % stenosis) was drawn by analyzing the spectral waveform of common femoral arteries. This mismatch is probably because of factors like obesity, bowel gases, use of higher frequency transducer and severe atherosclerotic disease arterial wall changes and calcification. The tibioperoneal arteries were adequately visualized in 37 out of 53 limbs (70%) limbs, possibly due to very slow, low velocity flow because of the severe proximal disease and diffuse arterial disease changes in arterial walls making the visualization difficult. The similar difficulties in visualization of tibioperoneal arteries are reported in a study by Mazzariol F, Ascher E et al[9].

The spectral waveform pattern in the distal arteries could depict about the normal or diseased proximal segment, with sensitivity of 83%, specificity of 95%, PPV of 83%, NPV of 95% and accuracy of 92%. These results matches with the study reported by Cossman DV, Ellison JE et al[10] who reported accuracy of 82% , sensitivity of 81 % and specificity of 96 % in diagnosis of iliac disease by common femoral waveform analysis. CDS revealed sensitivity of 86%, specificity of 98%, PPV of 94%, NPV of 95% and accuracy of 95% in detection of lesions in femoro-popliteal segments. Similar results have been reported by Koelemay MJ, den Hartog D et al[11] with sensitivity of 80% and specificity of 96% for detection of significant stenoses or occlusion in femoropopliteal segment. The tibioperoneal arteries constitute the maximum number of false positive and false negative results seen in the lower extremity arteries. They showed 12 false positive and 13 false negative results for the detection of the occlusion. The sensitivity of 70%, specificity of 86% and accuracy of 81% was seen for the detection of significant lesion by CDS in tibioperoneal arteries. Hatsukami TS, Primozich JF et al[12] reported sensitivity of 79% and 86% in posterior and anterior tibial arteries respectively due to similar difficulties in CDS evaluation of tibioperoneal arteries.

Out of the 9 false negative results for detection of >50% stenosis, 6 results were seen in aortoiliac segments. Two stenoses were present just distal to prior stenotic and occlusive lesion. The reasons for the low results for the detection of the stenotic lesion in our study could be the inadequate visualization of aortoiliac segment on CDS, presence of multisegmental disease and formation of large collateral vessels. Polak JF, Karmel MI et al[13] in their study have explained that the presence of large collateral branch shunts the blood flow away from the main arterial segment proximal to high grade stenosis and PSV measured at this stenotic lesion gives false results. Allard L, Cloutier G et al[14] demonstrated that the presence of multiple stenoses was an important limitation of duplex scanning for the detection and quantification of lower limb arterial disease.

The CDS could distinguish between normal and diseased segment of upper limb arteries with overall sensitivity of 87%, specificity of 95% and accuracy of 93 % with maximum sensitivity and specificity seen in brachial and radioulnar arteries (90% sensitivity and 95% specificity). These results compare well with the study reported by Wittenberg G, Schindler T et al[15] who reported the sensitivity of 90% and the specificity of 99% for detection of lesions by CDS in upper extremity arteries. The 3 out of 9 false positive and 4 out of 10 false negative lesions were in the subclavian artery, probably because SCA is the most difficult artery to scan with CDS in the upper limb because of its anatomic relations[16].

Overall CDS results when compared to angiography revealed sensitivity of 83%, specificity of 96%, PPV of 88%, NPV of 94% and accuracy of 92% in diagnosis of various lesions in peripheral arterial diseases. These results denote that Color Duplex Sonography (CDS) is a highly specific, relatively sensitive and accurate modality for identification and localization of various vascular lesions in peripheral arterial diseases. Quantitative and qualitative evaluation of the common femoral and distal subclavian Doppler waveform is a sensitive and accurate technique for the prediction of sig-

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nificant aortoiliac or proximal subclavian stenosis and is of particular value when full ultrasound assessment of aortoiliac and subclavian arteries is not feasible The morphology of the aneurysm i.e. thrombosis, patent lumen and changes in the parent artery could be visualized adequately with CDS and was better delineated compared to angiography which allowed evaluation of only the patent lumen of the aneurysms. CDS has a limited role in evaluation of tibioperoneal arteries in patients with significant peripheral arterial occlusive disease because of variety of factors related to disease, patients and also scanning technique. The high specificity (96%) and negative predictive value (94%) observed with Color Duplex Sonography in evaluating the hemodynamically significant vascular lesions is equivalent to angiography and also CDS is non-invasive, quick, inexpensive, readily available first level investigation. Hence, CDS can very well be used as a screening modality for the patients with symptomatic peripheral arterial diseases. Angiography will be needed in those patients in whom duplex scanning is inconclusive and while planning for interventional or operative procedure in patients having positive results on CDS for total evaluation of lesion and distal arterial runoff.

Table 1: Distribution of adequate visualization of arterial segments in lower and upper limbs by CDS

Segments (Lower limb)	No. Of Cases with adequate visualization on CDS (n=53)	Percentage Visualization on CDS (%)
Aorta to Ankle	37	70
Aorto-iliac	Direct - 32	60
	Indirect – 21	40
Femoro-popliteal	53	100
Tibio-peroneal	37	70
Segments (Upper limb)	n=29	--
Innominate to Wrist	25	86
Subclavian artery	Direct - 25	86
	Indirect - 4	14
Axillo-brachial	29	100
Radio-ulnar	29	100

Table 2: CDS versus angiography results in detection of various lesions in arterial segments of lower extremity

Arterial segments/ Results	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
IRA	67	93	80	88	86
CIA	83	97	94	91	92
EIA	90	98	90	98	96
CFA	100	100	100	100	100
PF	70	98	88	93	92
Prox SFA	92	100	100	97	98
Mid SFA	92	97	92	97	96
Distal SFA	82	97	93	92	92
Prox POP	85	97	92	95	94
Distal POP	82	97	93	92	92
Tibioperoneal	70	86	73	85	81
Overall	81	96	88	93	92

Table 3: CDS versus angiography results in detection of the lesions in various arterial segments of upper extremity

Arterial segments/ Results	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Innominate	-	100	-	100	100
Proximal SCA	88	95	88	95	93
Mid SCA	75	95	86	91	90
Distal SCA	83	96	83	96	93
Axillary	80	96	80	96	93
Prox BA	90	95	90	95	93
Mid BA	90	95	90	95	93
Distal BA	90	95	90	95	93
Radioulnar	90	95	90	95	93
Overall	87	95	88	95	93

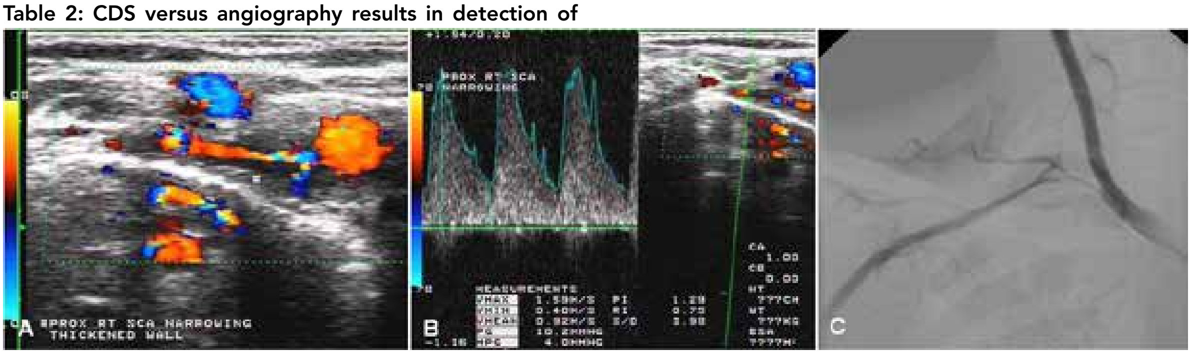

Fig.1: CDS images showing narrowing in proximal right SCA with color aliasing (1A) and increased PSV with spectral broadening (1B). Significant stenosis of proximal right SCA is seen on angiography (1C).

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Fig. 2: Color Doppler image show occlusive thrombus with absent color flow in left CFA (2A,) which is confirmed on angiography (2B). Power Doppler image in another patient shows right distal SFA thrombus with large proximal collateral vessel (2C).

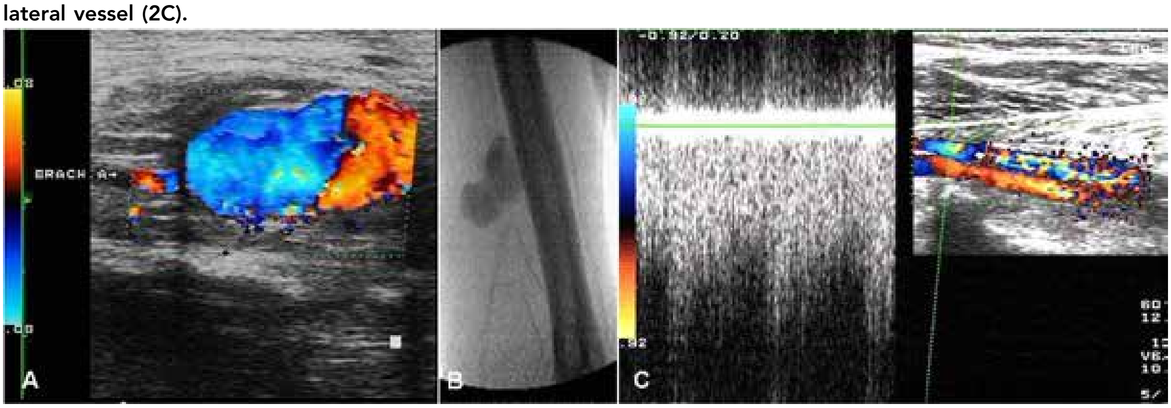

Fig.3: Left brachial artery pseudoaneurysm with swirling type of color flow (3A). Angiography image shows left brachial pseudoaneurysm (3B). CDS image of left popliteal AV fistula shows perivascular color artifact and arterialization of venous flow (3C).

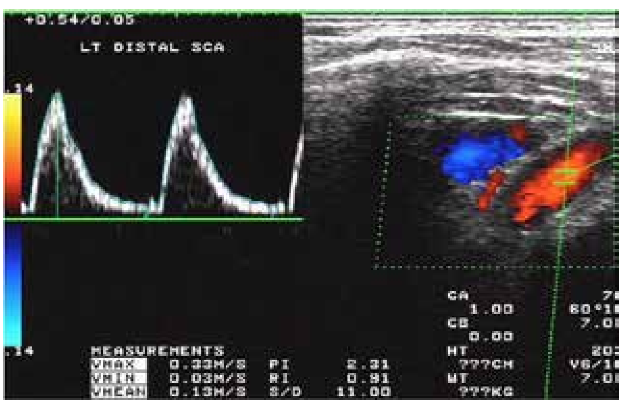

Fig 4: CDS of left distal SCA shows monophasic low velocity waveform suggesting significant proximal stenosis/occlusion. Occlusion of left SCA origin was seen on angiography.

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