B-Flow, Power Doppler and Color Doppler Ultrasound in the Assessment of Peripheral Arterial Stenosis: Comparison with 64-MD-CT Angiography

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Abstract

Background: B-flow is a new digital vascular ultrasound technique. B-flow is based on a digital subtraction principle. B-Flow provides direct visualization of blood echoes, extending the wideband resolution, high frame rates and wide dynamic range of B-mode to simultaneous imaging of blood flow and tissue.

Prior to surgical treatment, it is important to differentiate the degree of intra-arterial stenosis. A decision to operate in a vascular occlusion which has not been definitively diagnosed entails an unnecessary risk for the patient and is a substantial cost factor.

The purpose of this study is to evaluate whether B-flow can improve the ultrasonographic diagnosis of the degree of intra-arterial peripheral arterial stenosis over Color-Coded Doppler Sonography (CCDS) and Power Doppler (PD) in comparison to Multidetector CT-angiography (MD-CTA).

Patients and Methods: Vascular ultrasonography and multislice CT angiography (MD-CTA) were performed in 25 patients in Cairo University (2012-2015) between 27 and 60 years of age with suspected peripheral intra-arterial stenosis who had been referred for CT angiography.

Results: Comparison between the measured grade of intra-arterial peripheral arterial stenosis using different sonographic modalities with grade of stenosis measured by CTA showed there was no significant difference between B-Flow and CTA results (p=0.289); and a significant difference when CCD and PD were used (p=0.00 and 0.01 respectively).

Conclusion: B-flow improves the diagnosed of intra-arterial stenosis compared to other ultrasound techniques, offering a more accurate depiction of the vessel lumen. The quantification of the degree of stenosis shows a very good correlation to MD-CTA. However, CCDS remains necessary to quantify flow velocities in order to determine haemodynamic relevance.

Key Words: B-Flow Ultrasound – Intraarterial stenosis – Multislice CT.

Introduction

B-FLOW provides direct visualization of blood echoes in a display just like that of B-mode. Because it images blood flow and its surrounding anatomy simultaneously, and eliminates the need for overlays, the resulting images provide a clear, unobstructed view of the vessel lumen. The gray scale presentation of the flow data is also very intuitive, requiring no mental translation of the pixel data into velocity or power information [1].

B-Flow provides direct visualization of blood echoes, extending the wideband resolution, high frame rates and wide dynamic range of B-mode to simultaneous imaging of blood flow and tissue. The result is exceptional spatial, temporal and contrast resolution in blood-flow and vessel-wall display, which may improve diagnostic confidence in the evaluation of complex hemodynamics, permit earlier detection of peripheral vascular disease, and potentially providing more clinical information than other imaging modalities [2].

The differentiation of the degree of intra-arterial stenosis is essential before surgical intervention. The decision to operate in a vascular occlusion which degree has not been definitively characterized entails an unnecessary risk for the patient [3].

The purpose of this study is to evaluate whether B-flow can improve the ultrasonographic diagnosis of the degree of intra-arterial peripheral arterial stenosis over Color-Coded Doppler Sonography (CCDS) and Power Doppler (PD) in comparison to Multidetector CT-angiography (MD-CTA) [3].
Patients and Methods

This observational, cross sectional study was conducted at the Radiology Department of Cairo University Hospitals from 2012 – 2015. Detailed explanation of the study was informed to the patients before their procedures.

Vascular ultrasonography and multislice CT angiography (MD-CTA) were performed in 25 patients between 29 and 60 years of age with suspected peripheral arterial intra-arterial stenosis who had been referred for CT angiography.

Inclusion criteria:
• Any patient with upper or lower limb arterial ischemia with suspected intra-arterial stenosis.

Exclusion criteria:
• Patient with elevated renal functions.

All patients were subjected to the following:
• Full history: With special emphasis on history of diabetes, smoking and hypertension.
• Laboratory Investigations: Renal functions.
• Preparation: Fasting for 6 hours before Multidetector CT angiography (MD-CTA) and ultrasound.

A- All patients had the following done:

**MD-CTA:**

The patients were examined using a standard protocol with a 64 detector CT scanner (Toshiba Aquilion 64, Toshiba Medical Systems). Collimation and table feed were 64 x 0.6mm, rotation time 0.33s, pitch 1, slice thickness 1mm, reconstruction interval 0.5mm. Tube voltage was set to 120kV.

The contrast agent was injected into a large upper limb vein as a bolus using a dual head power injector with a flow rate of 5ml/s. 120ml Omnipaque (iohexol) with an iodine concentration of 300mg/ml was applied followed by 50ml saline. The appropriate scan delay after contrast agent application was determined by semiautomatic bolus tracking. A threshold of 100 HU was selected for the tracking ROI. The imaged volume included the entire arterial system to be imaged.

For the detection of stenoses, thin slice maximum intensity projections with were reconstructed. CT angiograms were analyzed according to NASCET criteria. The degrees of stenosis was computed from measurements on multiplanar reconstructions using VITAL workstation vessel probe analysis with automated vessel analysis tool. The degree of stenosis was evaluated by the minimal intrastenotic diameter in comparison to the poststenotic diameter.

**Vascular US:**

An examiner independently performed vascular ultrasound examinations of the peripheral vessels by means of CCDS, PD and B-flow with a multifrequency linear probe (3.4-10.8MHz). The ultrasound device (Logiq P6, GE Medical Systems) features a high performance processor and allows the documentation of dynamic image sequences in cine mode by a digital frame buffer. This was used to perform a comparative assessment between CCDS, PD and B-flow.

The flow parameters were selected according to the automatic presets on the ultrasound device. The color gain was selected just as high as it is necessary to avoid overwriting artifacts (i.e., color pixels outside the perfused lumen of the vessel). Additionally, an automatic image gain optimization could be selected. A transmitter output of 100%, an average image correlation and an average image rate were chosen for all ultrasound modalities employed.

US grading of the intra-arterial stenosis was performed by comparing the residual lumen to the relative distal uninvolved artery.

B- A radiologist performed a quantitative evaluation of the stenosis of MD-CTA guided by Vitrea software automated vessel analyses blinded to the results of the ultrasound preformed by a second independent radiologist.

Results

In all patients with intra-arterial stenosis, it was possible to appraise intra-stenotic and post-stenotic blood flow using all US modalities.

Usually intra-arterial stenoses could be imaged in their diameter extents with B-flow just about as well as with MD-CTA, while the deviations were larger for CCDS and PD.

The analysis of the measurements for the intrastenotic and poststenotic diameters and the measured degree of stenosis according to the NASCET criteria showed differences for CCDS, PD and B-flow techniques compared to MD-CTA.
Statistical analysis:

Data were statistically described in terms of mean ± standard deviation (±SD), median and range when appropriate. Comparison between the different modalities and the CT was done using paired t-test for paired (matched) samples. Correlation between various variables was done using Pearson moment correlation equation for linear relation in normally distributed variables and Spearman rank correlation equation for non-normal and or monotonic non-linear relation. p-values less than 0.05 was considered statistically significant. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) release 15 for Microsoft Windows (2006).

Fig. (1): Graphical representation of the statistics of intra-arterial stenosis and occlusions in the study population across four modalities; CT angiography (CTA), B-Flow (BF), Color Coded Doppler (CCD) and Power Doppler (PD).

Fig. (2): Case 2 showing left CIA stenosis of 83% (A) CTA MIP image demonstrating the stenosis of the left CIA origin (yellow arrow). (B) CTA vessel probe analysis demonstrating a minimal intrastenotic diameter of 1.3mm and a post stenotic diameter of 7.6mm corresponding to a 83% stenosis.

Fig. (3): Same patient as shown in Fig. 20 (A) SD, shows a high-stenosis of the CIA with maximal systolic flow velocity of about 350cm/s. (b) CCDS detected a minimal intrastenotic diameter of 1.7mm and a poststenotic diameter of 4.9mm, indicating a diameter stenosis of 66%. (C) PD detected a minimal intrastenotic diameter of 2.6mm, and a poststenotic diameter of 5.3mm, corresponding to a 51% stenosis. (D) B-flow detected a minimal intrastenotic diameter of 1.4mm, and a poststenotic diameter of 6.0mm, indicating a 77% stenosis.
Discussion

Based on the established normal and abnormal features of spectral waveforms and B-flow findings, a set of criteria for classifying diseased lower extremity arterial segments has been developed [4].

Minimal disease (1% - 19% diameter reduction) is indicated by a slight increase in spectral width (spectral broadening), without a significant increase in PSV. This minimal spectral broadening is usually found in late systole and early diastole. Moderate stenosis (20% - 49% diameter reduction) is characterized by more prominent spectral broadening and by some increase in peak systolic velocities. High-grade stenosis (50% - 99% diameter reduction) produces the most severe flow disturbance, with markedly increased peak systolic velocities [5].

In the current study, we chose MD-CTA as the reference method because of its high local spatial resolution.

Although all ultrasound techniques reliably detected residual flow in most of the patients in the current study, compared to widely-used US techniques such as CCDS and PD, B-flow additionally makes it possible to detect the pre-stenotic, intra-stenotic and post-stenotic flow simultaneously, especially in elongated vessels. This is also facilitated by the fact that high-velocity and low-velocity flow phenomena are registered at the same time without flow artifacts [6].

The present study used vitrea workstation automated vessel analysis for interpretation of MD-CTA findings as opposed to manual measurements of the stenosis used in Clevert et al. study.

The present study’s findings are in concordance with Clevert et al., in showing the B-flow mode correlates best with CTA with a coefficient a coefficient of 0.987 (with a level of significance \( p<0.0001 \)), while PD and CCDS measurements only yielded correlation coefficients of 0.797 and 0.813, respectively.

Conclusion:

B-flow improves the diagnosis of intra-arterial peripheral arterial stenosis compared to other ultrasound techniques, offering a more accurate depiction of the vessel lumen. The quantification of the degree of stenosis shows a very good correlation with MD-CTA. However, CCDS remains necessary to quantify flow velocities in order to determine haemodynamic relevance.

References


