Analysis of Doppler waveforms in the screening and investigation of lower-limb peripheral arterial disease

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Azzopardi Y.M. et al (2019). Agreement of clinical tests for the diagnosis of peripheral arterial disease. Prim Care Diabetes. Vol 13, pp 82-86.

SUMMARY

50 patients with type 2 diabetes mellitus underwent bilateral lower limb screening for peripheral arterial disease (PAD), to assess agreement of the 6 most commonly-used screening methods for identifying PAD (palpation, ankle-brachial pressure index (ABPI), toe-brachial pressure index (TBPI), absolute toe pressure (ATP), transcutaneous oximetry (TcPO2) and Doppler waveforms). Out of 100 limbs, Doppler waveforms were most likely to indicate PAD (93%), followed by TBPI (72%), ABPI (57%), ATP (35%), TcPO2 (30%) and palpation (23%).

PROS

These findings demonstrate significant disagreement between these commonly-used screening tools, and indicates that Doppler waveform screening is most likely to detect patients with PAD and palpation is least likely to detect patients with PAD.

CONS

No gold-standard diagnostic imaging was performed to confirm presence of PAD e.g. arterial duplex or CT angiography, therefore the precise sensitivity, specificity, positive and negative predictive values of each screening technique cannot be determined

Patients with open wounds, history of lower limb amputation or revascularisation history were excluded, which is likely to have skewed the study population in favour of patients with mild-moderate PAD as opposed to severe limb-threatening PAD, which can affect the most appropriate screening modality to use.

IMPACT ON PRACTICE

This study demonstrates the importance of not relying solely on one screening tool for identification of PAD, and of correlating positive screening tests with diagnostic imaging. Further investigation to determine the sensitivity and specificity of each screening tool correlated with diagnostic imaging would be of benefit to highlight the most accurate combination of screening tools for identifying PAD.

Descotes J and Cathignol D. (1975). Classification of changes in circulatory rate in the arteries of the lower limbs. Transcutaneous measurement by Doppler effect. Nouv Presse Med. Vol 4, pp 2091–3

One of the early attempts to classify waveforms was in 1975. They distinguished between 5 types of Doppler waveforms (figure 1) from normal (type 0 or N) to most pathological (type 4).

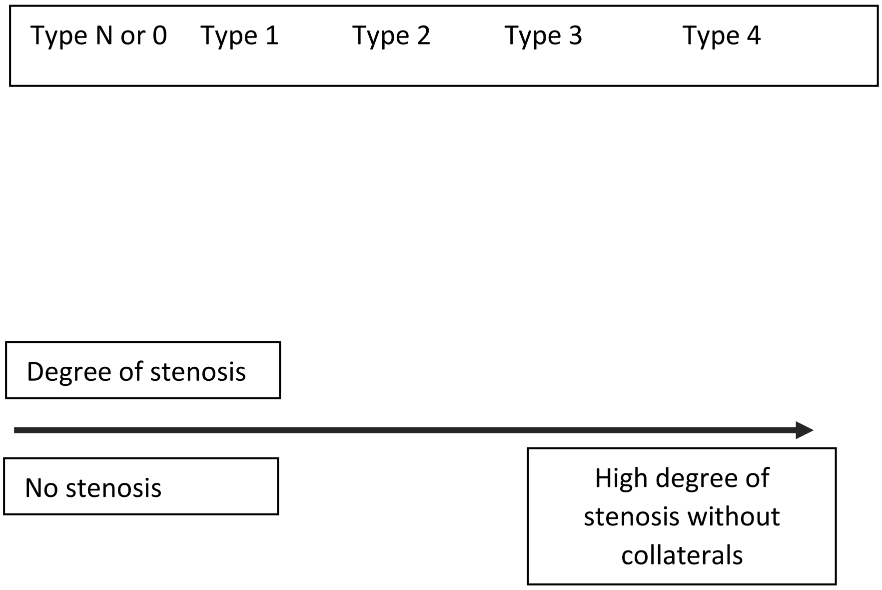

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Figure 1: Descotes and Cathignol classification.

PROS:

Illustration of the waveforms is useful in demonstrating the change of waveform shape from normal to presence of disease. Describes arterial waveforms according to the number of phases and relates them to the different stages of arterial wall damage.

CONS: Efficacy of any classification depends on how many waveforms can be identified as belonging to a category within that classification. Since there is a limited range of waveforms here, some studies have shown that the Descotes and Cathignol method has the most uncategorised waveforms amongst vascular physicians.

IMPACT ON PRACTICE

Although the waveforms then did not have names as we know them now, the representation of the shape and associated detailed descriptions paved the way towards understanding that the greater the number of phases and the sharper the upstroke the healthier the artery and vice versa.

Spronk S. et al (2005). Value of the duplex waveform at the common femoral artery for diagnosing obstructive aortoiliac disease. J Vasc Surg. Vol 42, pp 236-42.

SUMMARY:

This group used 381 aortoiliac segments to classify waveforms at common femoral artery (CFA) in to four groups as per figure 2.

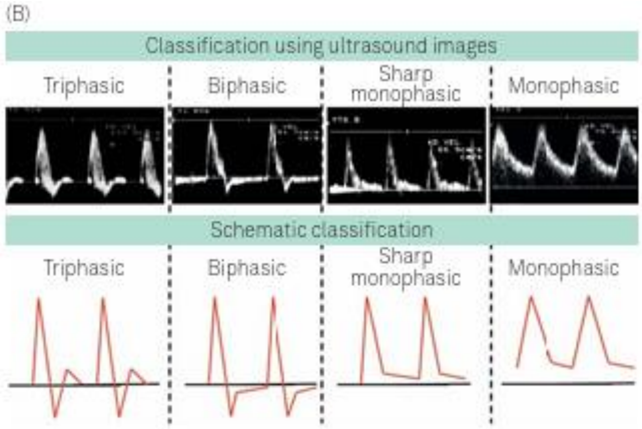

Figure 2: Spronk et al. classification.

Poor monophasic waveform at the CFA was a reliable predictor of significant aortoiliac disease (92% predictive value) and the sharp monophasic waveform was a reliable predictor of occlusive superficial femoral artery disease.

PROS:

Diagnostic accuracy of the waveforms were compared to a gold-standard method such as magnetic resonance angiography, therefore making this a more reliable study in determining the accuracy, sensitivity, specificity, positive and negative predictive values of waveforms in detecting significant obstructive aortoiliac disease.

CONS:

Very basic classification. Four waveforms do not really cover the wide breadth of waveforms seen in daily practice. Waveform interpretations were made from prints and not real time duplex scanning; this made some waveforms nondiagnostic due to artifact.

IMPACT ON PRACTICE:

This study provides evidence that in practice there is high degree of confidence that a haemodynamically significant stenosis is present if a monophasic/poor monophasic waveform is obtained. This may be useful when scanning the entire length of aortoiliac arteries is difficult due to e.g. obesity, gas, heavy calcification. It can provide a first-line rapid health evaluation of the aorto-iliac segment. However, care needs to be taken not to completely dismiss triphasic and particularly biphasic waveforms as being 100% indicators of no presence of significant disease. In certain instances, waveforms recorded at sufficient distances from a stenosis can normalise, and this was seen in one quarter of patients in this study.

Mahe G, et al. (2018). College of the 2519 French Vascular Medicine Teachers (CEMV) statement: Arterial Doppler waveforms analysis 2520 (simplified Saint-Bonnet classification)]. J Med Vasc. Vol 43, pp 255-61.

This classification was first proposed in 2017 and distinguishes between 13 types of waveforms (figure 3). Some of the main ones are: Type N (describes a triphasic waveform); type A (a biphasic waveform with the disappearance of forward flow); and type B (a sharp monophasic waveform). Types C/D describe the attenuation of type B waveforms with loss of sharp peak systolic velocity rise time and more rounded appearance. Type E corresponds to flow velocity close to zero. A further five types are described which correspond to those described above with a continuous flow component and denoted CF. Type 0 represents no flow and type U is undefined.

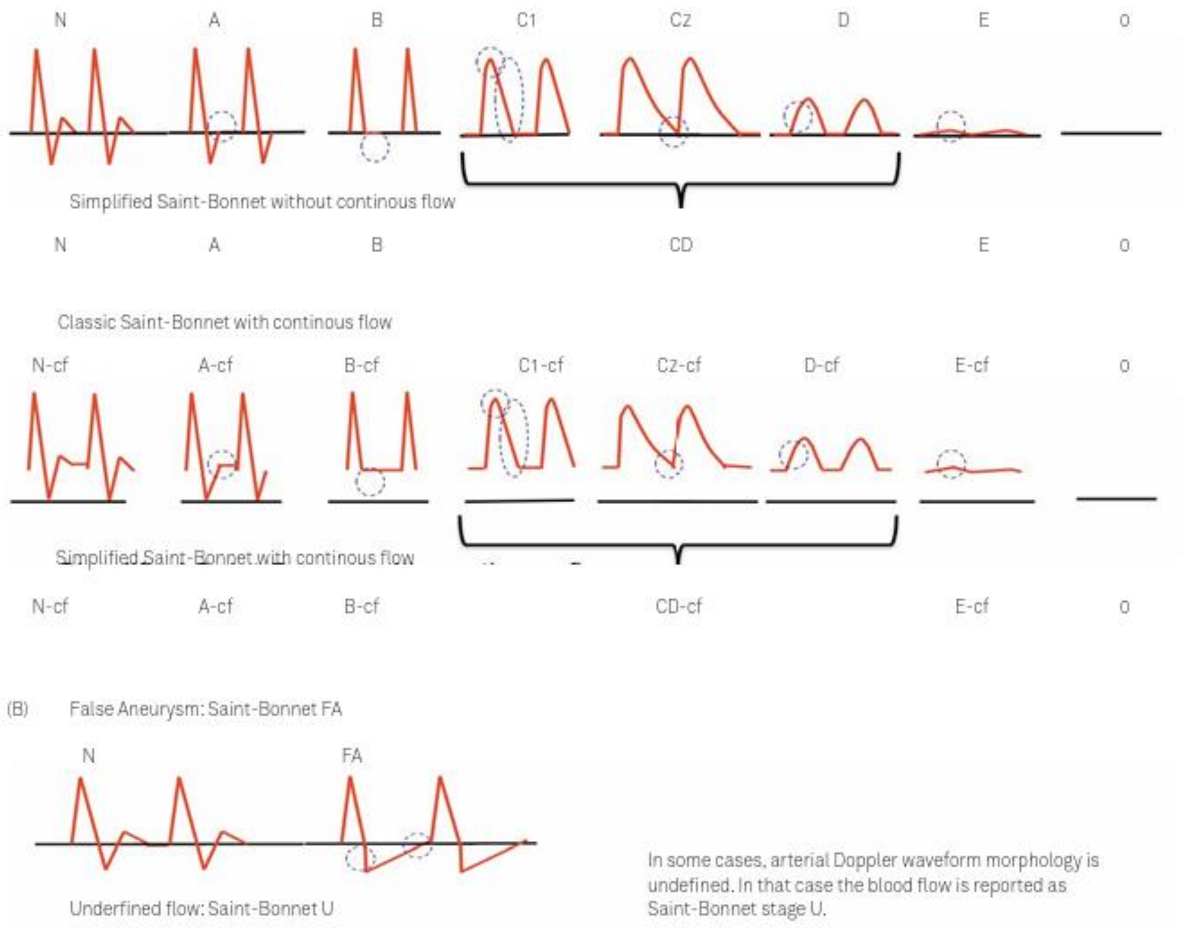

Figure 3: Saint Bonnet classification.

PROS

More waveform types which cover a wider breadth of waveforms seen in clinical practice. They add a categorisation for continuous flow which are often a topic of contention especially when a waveform appears pulsatile and resembles triphasic but is all above baseline. Multiple studies (one mentioned below) have shown that this classification has potential for clinical standardisation of Doppler waveform morphology.

CONS

The severity of lesions range from N to 0 with N being most normal and 0 being most severe, however the in between waveforms are open to much interpretation. Since there are many more waveform types in this classification, it can appear more complicated and it may take longer to familiarise and be able to categorise the waveforms than with those methods using less descriptors.

IMPACT ON PRACTICE

This shows that the use of arterial Doppler waveform morphology classification is recommended to describe Doppler waveforms in patient care and research studies. Clinicians and vascular scientists need adequate training to familiarise themselves with these classifications and to correlate them properly with various stages of arterial disease.

Guilcher et al. (2021). Comparison of the Use of Arterial Doppler Waveform Classifications in Clinical Routine to Describe Lower Limb Flow. Vol 10, pp 464.

SUMMARY
1033 lower limb arterial waveforms were obtained and analysed by 11 vascular physicians and classified using the Descotes & Cathignol (1975), Spronk et al (2005) and simplified Saint-Bonnet (2017) criteria. PAD severity was determined using the Fontaine classification scale. Doppler waveforms were most effectively categorised using the Saint-Bonnet system (98.2%), followed by Spronk et al (91.3%) and Descotes & Cathignol (76.8%). Most normal waveforms were identified in asymptomatic patients, and most abnormal waveforms were identified in symptomatic patients.

PROS
This study highlights the significant variability in waveform classification, and indicates that the simplified Saint-Bonnet guide is the best system for classification of peripheral arterial Doppler waveforms, as it contains the widest range of waveform types and includes classification of waveforms with continuous antegrade flow throughout diastole.

CONS
Patients with severe PAD had low prevalence in this study, resulting in fewer waveforms being present from the severely abnormal end of the spectrum for each classification system. Additionally, presence of PAD was assessed using the Fontaine scale which grades severity of symptoms, but did not utilise diagnostic imaging to confirm and characterise presence of PAD.

IMPACT ON PRACTICE
Standardisation of Doppler waveform descriptors would be of great benefit to the vascular community, to improve interpretation of Doppler waveforms as reported on vascular ultrasound reports. The simplified Saint-Bonnet classification system is the most effective system for classifying waveforms due to the increased number of waveform types represented, however the correlation between waveform type and characterisation of PAD was not assessed in this study.

Kim et al. (2020). Interpretation of peripheral arterial and venous Doppler waveforms: A consensus statement from the Society for Vascular Medicine and Society for Vascular Ultrasound. Vasc Med, Vol 25, pp484-506.

SUMMARY

Interpretation and classification of Doppler waveforms varies, resulting in well-documented instances of repeat examinations being requested due to misunderstanding of waveform types in vascular ultrasound reports. This paper seeks to standardise Doppler waveform descriptors in order to standardise reporting and improve interpretation of vascular ultrasound examinations.

PROS

Simplification of waveform phasicity to be limited to ‘multiphasic’ (flow reversal component) or ‘monophasic’ (no flow reversal component), and ‘high resistance’ (sharp systolic upstroke, brisk systolic downstroke) or ‘low resistance’ (prolonged systolic downstroke with lack of end-diastolic notch), which addresses the various reported definitions of ‘triphasic’ and ‘biphasic’ which has historically caused confusion regarding classification and interpretation of Doppler waveforms.

CONS

The above descriptors do not determine whether the waveform obtained is normal for a given arterial circulation, only how to describe the waveform itself. Knowledge of what waveform characteristics are considered ‘normal’ is still required for interpretation of vascular ultrasound reports; lack of knowledge in this area is likely to be a significant contributing factor for poor interpretation of waveform types and characterisation of PAD.

IMPACT ON PRACTICE

Standardisation of Doppler waveform descriptors is likely to improve diagnostic accuracy of PAD characterisation using Doppler waveform analysis, resulting in more efficient treatment pathways and fewer instances of repeated examination requests. However, an appropriate level of understanding of vascular physiology and the difference between ‘normal’ and ‘abnormal’ flow patterns is still of paramount importance for effective diagnosis and management of PAD.

CONCLUSIONS:

Over time studies have shown the usefulness of Doppler waveforms in the detection and evaluation of PAD. But on the other hand, the absence of standardization in waveform descriptors and what classifies as normal/abnormal has resulted in much confusion in clinical practice. Attempts have been made to clarify and standardise key definitions and descriptors of arterial waveforms as well as describing alterations of waveforms with physiological changes and disease states. Although this has improved the reporting and interpretation somewhat, more still needs to be done to reduce the heterogeneity of Doppler waveform reporting.

FUTURE HORIZONS:

More work is needed in describing waveform morphology and correlating any changes relative to severity of disease in a wider range of patient types, for example renal artery disease, the differences in diabetic patients with and without ulcers, arteriovenous fistula patients etc. There is scope for a future study to create a Delphi consensus of waveform terminology used by vascular scientists/physicians and how to interpret them.

None of the classifications mentioned above can propose an exhaustive description of the various Doppler flow waveforms seen in a clinical setting, therefore classification and interpretation errors remain. One proposal to reduce these errors has been to automate the categorisation process with the use of computer-aided technology such as artificial intelligence where some preliminary work has begun (McBane et al. 2022, Vasc Med; 27: 333-42).