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REVIEW

Three-dimensional Ultrasound in the Management of Abdominal Aortic Aneurysms: A Topical Review

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WHAT THIS PAPER ADDS

This review introduces vascular specialists to three-dimensional ultrasound and its present and future potential applications in patients with abdominal aortic aneurysms. The literature, evidence, and current areas of research, including measurement of diameter and volume, endoleak detection, and rupture risk prediction are covered.

Three-dimensional (3D) ultrasound is an evolving modality that may have numerous applications in the management of abdominal aortic aneurysms. Many vascular specialists will not be familiar with the different ways in which 3D vascular ultrasound data can be acquired nor how potential applications are being explored by researchers. Most of the current literature consists of small series and single-centre experience, although clinical themes such as measurement of abdominal aortic aneurysm volume and surveillance following endovascular repair are emerging. The aim of this topical review is to introduce clinicians to the current concepts of 3D ultrasound, review the current literature, and highlight avenues for further research in this new and exciting field of vascular imaging.

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INTRODUCTION

Possible clinical applications of three-dimensional (3D) ultrasound (US) have been described in obstetrics, gynaecology, urology, cardiac, and breast imaging.[1] Given the prominent role of ultrasound in the initial diagnosis of vascular disease, it is not surprising that there is growing interest in the use of this technology. Presently, 3D-US is not integrated into the diagnostic armamentarium in most vascular clinics, but has been used in research settings to image carotid, lower limb, and abdominal aortic disease.[2–5]

3D-US is a rapidly developing and exciting new imaging modality that has the potential to replace computed tomographic angiography (CTA) for a number of clinical applications in the management of abdominal aortic aneurysm (AAA). Until recently, clinical implementation has been limited by the need for laborious post-processing software and the absence of well-defined clinical indications.

The aim of this topical review is to introduce vascular specialists to the current 'state-of-the-art' of 3D-US by presenting the current knowledge and near-future applications of 3D-US in the management of AAA.

Three different ways to generate 3D-US images

There are three main approaches to the acquisition of 3D-US data: mechanical, matrix, and freehand (Fig. 1).

Mechanical 3D-US transducers consist of a motor contained within the transducer that moves a single array of up to 512 piezoelectric crystals acquiring a series of two-dimensional (2D) images. These 2D images are then placed sequentially into a 3D volume reconstruction. The volume that can be imaged is relatively small compared

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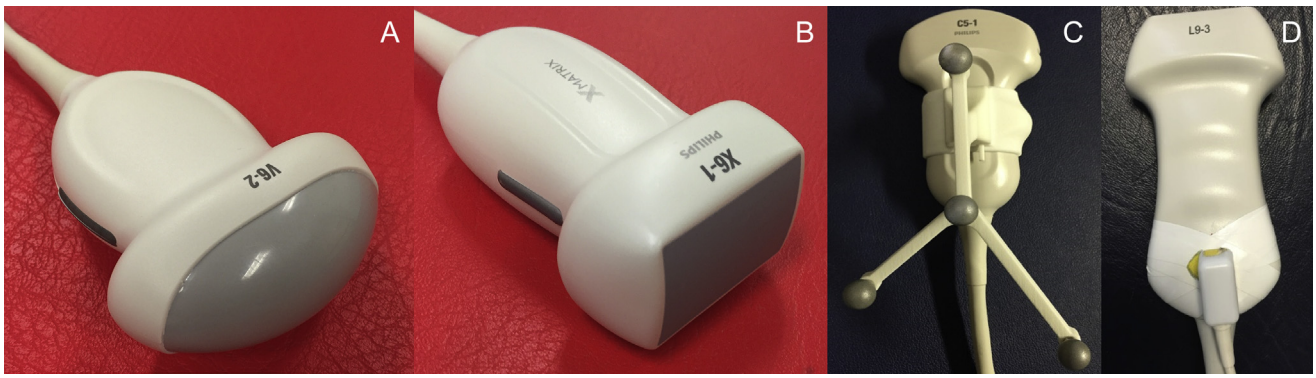

Figure 1. Three-dimensional ultrasound techniques. From left to right: (A) mechanical transducer; (B) matrix transducer; (C) standard curved transducer adapted for freehand scanning using optical tracking; (D) standard linear transducer adapted for freehand scanning using magnetic tracking.

with a matrix transducer. Hence, only small sections of anatomy can be imaged using this technology.[1,6–8]

A typical commercially available matrix 3D-US transducer is composed of grids up to 9,000 piezoelectric crystals. The imaging volume is larger than mechanical transducers and image acquisition at around one second is much faster. Owing to the grid of crystals and electronic sequencing, image acquisition can be performed in all three image planes. The image resolution is slightly reduced compared with the mechanical transducer. The fixed crystal grid in matrix scanning can image over a longer and wider range than a mechanical probe, but the volume still remains limited. Therefore, for long vessels the anatomy cannot always be seen in a single acquisition.

"Freehand" 3D-US uses position sensing and standard 2D, "off-the-shelf", transducers coupled to an external tracking system. The most popular approach is to use sensors mounted on a conventional 2D transducer, which are tracked by an optical system or within a magnetic field. The orientation of the probe can be determined by the system and allows reconstruction of the US images into a 3D volume. This method gives greater operator freedom as transducers can be passed over a large region of interest and the transducer position can be manoeuvred to avoid obstacles such as bowel gas and acoustic shadowing (Table 1).[1,6–8]

PUBLISHED CLINICAL STUDIES

The evidence base on 3D-US is growing, but there are currently insufficient data or comparative studies sufficient to perform a systematic review or meta-analysis. However, three main applications of 3D-US relevant to AAA have been studied: (1) measuring AAA size, including maximum diameter and volume; (2) endoleak detection following endovascular aneurysm repair (EVAR); and (3) rupture risk prediction models (Table 2).

Measuring AAA size

Maximal diameter. Accuracy and reproducibility in the measurement of AAA diameter is paramount as it governs current referral thresholds for AAA repair, surveillance following EVAR, and research investigating the effects of pharmaceutical compounds on AAA growth rates. Although AAA diameter is the conventional indication for repair, the optimal imaging modality remains a matter of debate.[9] Operator variability in ultrasound imaging is predominantly caused by variation in the orientation of scanning planes between operators.[10–12] 3D-US has the potential to eliminate these shortcomings as the diameter of the AAA can be measured in the true axis as achieved by CTA. This allows measurements in orthogonal planes, reducing user dependency, and potentially making measurements more accurate and reproducible.

3D-US has been investigated in three studies from two centres with the aim of improving the accuracy of measuring maximum diameter assessment in AAA and EVAR surveillance.[2,3,13] Using the same semi-automated software, two types of maximum diameter were described in each of these studies: (1) the *US dual-plane diameter* was determined on the US unit at the bedside using existing software on the US system where transverse and longitudinal views were displayed simultaneously in a live split image (Fig. 2); (2) the *centreline diameter* was defined "off line" on a workstation as the maximum diameter perpendicular to a centreline, semi-automatically generated in postprocessing software (Fig. 3).

Diameter measured using the US centreline achieved better agreement with CTA (mean difference 1.8 mm [centreline] vs. 2.6 mm [dual plane]) but equivalent reproducibility compared with that of dual-plane diameter in small AAAs. In post-EVAR patients, interoperator reproducibility measures of 4.4 mm were acceptable but slightly inferior compared with the results obtained in small, untreated AAAs, with an interoperator reproducibility of 3.0 mm.[3] This was explained by more hostile residual sacs being larger, reconfigured and containing an EVAR device. Similar reproducibility was reported in a previous study using a mechanical transducer.[13]

The 3D-US dual-plane measurement of diameter is, to the best of the authors' knowledge, the only 3D-US application that is used routinely in clinical practice (Fig. 2). Using this

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