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Follow-up on Small Abdominal Aortic Aneurysms Using Three Dimensional Ultrasound: Volume Versus Diameter

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WHAT THIS PAPER ADDS

Three dimensional ultrasound can estimate volume changes as part of the surveillance of abdominal aortic aneurysms (AAAs). It was observed that more than one third of the small AAAs considered to be stable based on diameter alone, were growing in volume. In the post-hoc analysis, which may be strongly biased, patients with a stable diameter and a growing volume during follow-up were more prone to leaving surveillance in favour of AAA repair than patients whose AAA diameter and volume remained stable. In AAA surveillance volume measurement appears to be a potential adjunct to AAA surveillance.

Objectives: Rupture risk in abdominal aortic aneurysms (AAAs) is assessed using AAA diameter; yet 10% of ruptures occur in a small aneurysm. This underlines the inadequacy of diameter as a standalone parameter. In this prospective follow-up study, ultrasound determined aneurysm diameter was compared with aneurysm volume determined by three dimensional ultrasound (3D-US) in a group of 179 AAAs.
Design: This was a prospective cohort study with repeated diameter and volume measurements by 3D-US.
Material and methods: In total, 179 patients with small infrarenal AAAs (diameter 30—55 mm) were enrolled consecutively. At enrolment and at 12 month follow-up, maximum diameter, using dual plane technique, and three dimensional volume were measured. Based on a previous accuracy study, significant change in diameter and volume were defined as an increase exceeding the known range of variability (ROV) of each US technique; ±3.7 mm and ±8.8 mL, respectively. Post-hoc Kaplan—Meier analysis was performed to estimate time to conversion to treatment after the conclusion of the follow-up period between two groups.
Results: In total, 125 patients (70%) had an unchanged diameter during follow-up. In this group, 50 patients (40%) had an increasing aortic volume. Forty-five (83%) of the 54 patients with an increasing aortic diameter showed a corresponding volume increase. During a median follow-up of 367 days (364—380 days), a mean increase in diameter of 2.7 mm (±2.6 mm) and a mean increase in volume of 11.6 mL (±9.9 mL) were recorded. In post-hoc analysis, it was found that more AAAs with a stable diameter and a growing volume than AAAs with a stable diameter and volume were undergoing aortic repair during follow-up, based on the maximum diameter.
Conclusion: In this cohort of small AAAs, 40% of patients with a stable diameter had an increasing volume at 12 month follow-up. From this perspective, 3D-US could have a future supplemental role in AAA surveillance programmes.

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INTRODUCTION

As a decision aid for elective repair of abdominal aortic aneurysms (AAAs) and rupture prevention, the parameter most closely related to rupture is by far, maximum diameter and to some extent gender and expansion rate.[1—5] Nevertheless, up to 10% of ruptured AAA are <55 mm,[1,6—9] underlining that diameter may be inadequate as a stand-alone parameter for intervention.

Previously, three dimensional computed tomography (3D-CT) has been used to demonstrate that some AAAs increase in volume despite having a stable maximum diameter,[10—12] which emphasizes the potential role of volumetric measures.[13] Until recently, ultrasonic quantification of AAA

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volume has not been possible, and prior reports all rely on 3D-CT volume reconstructions,[10,12,14,15] which is a concern for follow-up because of the radiation exposure and contrast burden.

Three dimensional ultrasound (3D-US) can determine AAA volume with good reproducibility,[16] and the 3D-US derived dual plane US technique can provide a more accurate image plane orientation and diameter estimation than the two dimensional ultrasound technique (2D-US).[17] Furthermore 3D-US has demonstrated an improved agreement with CT following endovascular aneurysm repair (EVAR),[16] but its use for volume estimation in AAA surveillance remains unexplored.

This surveillance study of patients with small AAAs aimed to explore the changes in aortic diameter and volume using a new non-invasive 3D-US technique.

MATERIAL AND METHODS

Patients and study design

Among patients with small AAAs, 3D-US was added to a standard surveillance programme to detect any disagreement between diameter and volume growth patterns, using the maximum antero-posterior diameter estimated on dual plane US as the gold standard. The study period was defined as the time from enrolment to 12 month follow-up.

Between August 1, 2013 and September 30, 2015, a total of 1488 patients with AAA were seen in the vascular department's outpatient clinic. Of these patients, 412 had an AAA with an initial maximum US diameter between 30 and 55 mm on dual plane US and were thus eligible for the study (Fig. 1). Patients were recruited consecutively and enrolled if a successful dual plane US and 3D-US examination had been completed at their 12 month follow-up and if informed oral consent was provided. The exclusion criteria were prior abdominal aortic surgery, suprarenal aortic aneurysm, non-compliance, missing 12 month follow-up with an adequate 3D-US, and prior enrolment into other imaging studies. Further demographic data are presented in Table 1.

In total, 179 consecutive patients (146 men) completed the study with a median follow-up of 367 days (364−380 days). Of the 179 patients, 82 (66 men) were newly referred. Finally, 233 recruited patients were not enrolled because of: no available 3D-US examination at the 12 month follow-up (n=109), AAA surgery (n=48), non-AAA related death (n=52), and poor image quality (n=24). This resulted in a technical success rate for volume assessment of 88% (179/203).

After the follow-up period had concluded (September 30, 2015), a 13 month post-hoc analysis was performed, solely to assess the number of aortic repairs among the two groups of patients. The post-hoc period was not included in the primary follow-up period.

Oral informed consent was obtained from all patients, and the study was approved by the local ethics committee (H-6-2014-056). All patients undergoing intervention during the study and the post-hoc analysis, were treated in accordance with the European Society of Vascular Surgery (ESVS) AAA guidelines, and their volume information was not considered.[18]

Dual plane ultrasound imaging

Dual plane US imaging is a validated 3D-US derived technique that was implemented as a standard modality for AAA surveillance at the study centre prior to initiation of the present study.[17] With the dedicated 3D transducer (X6-1 xMATRIX, Philips Ultrasound, Bothell, WA, USA), the dual plane ultrasound technique enables simultaneous and real time display of both cross sectional and longitudinal imaging.

Dual plane imaging was used to locate the maximum cross sectional antero-posterior diameter (Fig. 2B) from the leading edge of the anterior wall adventitia to the leading edge of the posterior wall adventitia.[19] The longitudinal display was used to guide a correct cross sectional image plane. The maximum diameter measured on the cross sectional image was considered to be the gold standard (Fig. 2B). The range of variability (ROV) of the dual plane diameter estimation was ±3.7 mm according to a prior accuracy study in small AAAs.[17]

Non-fasting patients were examined in the supine position following 5 minutes of rest. Certified nurses and physicians experienced in vascular ultrasound performed the 3D-US investigations. The data were stored in an ultrasound picture archiving and communication system (IntelliSpace Cardiovascular 2.1, Philips, The Netherlands).

Three dimensional ultrasound volume estimation

With dual plane imaging, complete visualisation of the AAA in both the cross sectional and the longitudinal plane was attempted paying special attention to the neck (proximal extremity) and the aorto-iliac bifurcation (distal extremity). During breath hold and within 2 s, an electronic 3D acquisition of volume assessment was performed. All 3D-US acquisitions were handled offline on semi-automated quantification software (AAA-prototype v.2.0, Philips Research, Suresnes, France) by a single investigator (QG). Acquisitions obtained at inclusion and follow-up were handled at a minimum interval of 1 month to secure mutually independent volume quantifications.

Volume quantification was a two stage procedure based on a previously validated workflow protocol including usage of the same transducer and off-line quantification software as described in the study by Bredahl et al.[17] Briefly, the distal and proximal extremities of the aneurysm were manually defined; this was followed by an automated outlining of the inner vessel wall and quantification of a partial AAA volume. The physical dimensions of the transducer meant that the maximum length of the 3D reconstruction was limited to 60 mm, and denoted partial AAA volume (Fig. 2A).[17] From a prior accuracy study, the ROV of inter-observer volume assessment with 3D-US was ±8.8 mL.[17] The intra-observer ROV was ±6.6 mL, which is significantly lower than the inter-observer ROV.