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Advances in Imaging and Surveillance of AAA: When, How, How Often?

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ABSTRACT

Despite rapid technological developments for imaging the aorta, ultrasonography remains the method of choice for abdominal aortic aneurysm screening and surveillance. Randomised trials, conducted in the 20th century, have provided convincing evidence in favour of screening men at age 65 years, or older. However, in the 21st century the prevalence of aneurysms in 65 year old men has fallen by more than half, probably because of lower smoking prevalence and better cardiovascular risk prevention: screening or rescreening at an older age may be helpful. A recent meta-analysis has provided good evidence for surveillance intervals, with the majority of patients with screen-detected aneurysms (up to 4.5 cm diameter) being safely managed with 3-year surveillance intervals. Even for larger aneurysms, annual surveillance intervals are likely to be acceptable. This would reduce the number of surveillance visits by approximately half.

Advances in imaging of the abdominal aorta

Ultrasonography (US) remains the mainstay imaging modality for abdominal aortic aneurysm (AAA) screening and for the surveillance of patients with small AAAs for several reasons: relatively low costs, ability to be performed by non-expert technicians, high sensitivity, low interoperator variability (2–8 mm) and no radiation exposure [1]. Information from duplex US may be used to augment simple diameter measurements and evaluation of wall motion and compliance using Doppler imaging has been reported whilst three-dimensional US may provide additional information on AAA morphology. Contrast-enhanced US using second-generation sonographic contrast agents (stabilised microbubbles containing gases other than air) produces real-time contrast-enhanced grey-scale images [2]. However, whilst this technique may be useful in detecting endoleaks following endovascular repair of AAA, its role above non-contrast US in AAA assessment is yet to be defined.

High-resolution spiral computed tomography with intra-aortic iodine-based contrast (CTA), although able to provide more detailed information on AAA size and morphology, exposes patients to significant doses of radiation and risk of nephrogenic injury and is therefore less suitable as a screening and surveillance tool. CTA is however the current standard for pre-operative AAA assessment and advanced software on dedicated workstations enables advanced 3-D and multiplanar image reconstructions, allowing evaluation of whole vessel morphology and measurement of aneurysm diameters and lengths. Images may be reconstructed with reference to the aortic centreline, either manually, using double-oblique correction, or with automated software algorithms, and diameter measurements taken perpendicular to the axis of blood flow. However, measurement methods

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Abbreviations and Acronyms

AAA = abdominal aortic aneurysm

CT = computed tomography

CTA = computed tomographic angiography

MASS = Multicentre Aneurysm Screen Study

MRA = magnetic resonance angiography

UK = United Kingdom

US = ultrasonography

remain unstandardised and significant interobserver variability has been recorded, particularly for measurements using unformatted (axial) planar images [3,4]. Post-processing techniques also enable CT virtual intravascular endoscopy reconstructions, which may play a role following endovascular repair, but it does not appear to provide any additional information compared to axial CT images.

Dynamic magnetic resonance angiography (MRA) with intra-aortic gadolinium-based contrast gives excellent soft-tissue contrast without radiation exposure and performs equally as well as CTA in the diagnosis of AAA, with similar image reconstructions techniques available, but is costly and less readily available in most centres [5]. Both CTA and MRA are relatively contraindicated in patients with renal impairment (gadolinium contrast has been associated with nephrogenic systemic fibrosis) and there is evidence that unenhanced MRI using steady-state free-precession sequences that differentiate flowing blood and background tissue is a suitable alternative in such patients [6].

Intravascular ultrasound is a recent development and appears to provide equivalent information to CTA for AAA assessment [7]. Intravascular ultrasound may provide additional information concerning spatial configuration of aneurysm neck and visceral branches, and intra-vascular calcium and thrombus. However, currently it remains a costly and invasive procedure and is unlikely to have significant benefits over that of CTA in the majority of patients.

Although AAA diameter is the current gold standard for predicting rupture risk, a search for other biomechanical markers to stratify risk has led to a rise in development and investigation of advanced imaging techniques. Measurements of wall shear stress and wall shear rate are possible using microbubble contrast-enhanced ultrasound velocimetry techniques and phase-contrast MRA although the relationship of these variables to rupture risk is yet to be proven. One CTA-based computation study has suggested an association between increasing peak wall stress and AAA rupture risk [8] and there is on-going work to develop pulse wave imaging algorithms to measure arterial wall stiffness using duplex ultrasonography. Diameter asymmetry also has been reported to predict rupture risk [9]. The relationship of intraluminal thrombus and intramural calcium on rupture risk in AAA is uncertain, with conflicting evidence as to whether each is protective or a marker of increased risk. AAA calcification is masked by intravascular contrast in regular CTA imaging; however, this can be overcome by using dual-energy CT with two tube voltages that allow differentiation between calcium and blood vessel wall in the presence of contrast [10]. Biomechanical analysis software for CTA images is currently under development but more evidence is required before such data can be used clinically to predict rupture risk and as a basis for treatment recommendations.

Functional molecular imaging techniques have also been investigated for AAA [11]. CT-positron emission tomography with ^{18}F-fluorodeoxyglucose tracer has been used in the diagnosis and follow-up of mycotic aneurysms but its utility for predicting rupture risk is less clear, with conflicting evidence about the relationship between positive scans and AAA growth and rupture. More preliminary experimental work using inflammatory positron emission tomography-tracers such as iron oxide nonparticles (specific for macrophages), interleukin-2 and choline have been reported. Ultrasmall superparamagnetic iron oxide-enhanced MRA has been used to quantify phagocytic activity and inflammation in the AAA wall and intraluminal thrombus, and appears to be able to identify patients with more rapidly progressive AAA expansion [12,13]. However, further work is required to more fully delineate the relationship of visualised inflammation and rupture risk. Molecular biochemical luminescence and fluoroscopy imaging has been used in murine models of AAA to visualise bio-markers of inflammation, such as matrix metalloproteases, and neovascularisation, such as vascular endothelial growth factor, but the significance of these requires further investigation before translation into humans.

How should we screen for AAA?

Ultrasonography, a non-invasive and cheap technique, is highly specific and sensitive for the detection of AAA, usually defined as a maximum infra-renal aortic diameter of $\geq$ 3 cm. This diameter can be measured in both anterior to posterior and transverse orientations, although ultrasonography has a better reproducibility for the measurement of anterior to posterior diameters, with measurements variability of ± 2 mm being attainable after careful operator training [14]. Usually the external aortic diameter is used to define maximum aneurysm size, although in one of the largest trials dealing with AAA screening, the Multicentre Aneurysm Screening Study (MASS), measurements were based on the internal aortic diameter, which is relevant when considering the fate of a normal-sized (<3 cm) aorta [15].

Aortic screening can be performed by trained sonographers or vascular scientists. However, screening can add substantially to the workload and these specialists are over-skilled for the required single ultrasound test of the abdominal aortic diameter. Therefore a new role for screening technicians has been developed in the United Kingdom NHS AAA Screening Programme to undertake ultrasound aortic screening. These screening technicians complete a specific mandatory training for approximately 6 months, which includes interpersonal skills, ultrasound science, quality control, a mentored supervision followed by an assessment and accreditation process. Technological advances in ultrasonographic instrumentation with smaller and portable ultrasound machines providing improved accuracy have benefitted screening programmes.

The importance of ultrasonography has opened the door for hardware and software innovations and manufacturers are developing equipment, which is easy to use without the need of a specialised sonographer. One example is the AortaScan™, a