A standardised intraoperative ultrasound examination of the aorta and proximal coronary arteries

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Received 4 April 2006; received in revised form 31 July 2006; accepted 2 August 2006

Abstract

The aim of this study was to describe a standardised intraoperative ultrasound examination of the aorta and proximal coronary arteries for use in cardiac surgery using a handheld probe, to be used in conjunction with intraoperative transoesophageal echocardiography. Most cardiac surgery operations involving the use of cardiopulmonary bypass will result in significant manipulation of the ascending aorta with potential atheroma dislodgement which may result in atheroembolism. Accurate detection and localisation of aortic atheroma allows the surgeon to adjust the site of aortic manipulation and potentially avoid dislodging atheroma. A single surgeon experience from 1996 to 2005 of 1455 intraoperative ultrasound examinations. Coronary surgery 1214, valve surgery 369, aortic surgery 30, congenital surgery 74 and reoperations 105. Stroke 13, TIA 2, confusion 56, coma 24 h 8. In 591, ultrasound data were recorded in a custom database. Age 66 ± 0.5 (25–93) years, 69% males and coronary surgery 77%. Atheroma increased with distance from the aortic valve (P < 0.001), and with age, (P < 0.001). One third of patients more than 70 years had moderate or severe atheroma detected in the regions imaged by this technique.

1. Introduction

This paper seeks to describe a standardised intraoperative ultrasound examination of the aorta and proximal coronary arteries that is used in conjunction with intraoperative transoesophageal echocardiography during cardiac surgery. The distal ascending aorta and proximal arch are the sites of much aortic manipulation, but it is not adequately imaged by transoesophageal echocardiography due to air in the trachea and right main bronchus which impedes the ultrasound signal.

The aim of intraoperative screening of the aorta with ultrasound is to accurately detect atheroma that may be at risk of being dislodged during surgery. Ultrasound assessment for atheroma is more accurate than manual assessment [1]. Precise location of atheroma is determined by the position of the ultrasound probe on the surface of the aorta at that time and does not require any reference to other cardiac or aortic structures imaged.

The surgeon may cause atheroma dislodgement by passing a cannula through it, clamping it, suturing it, performing anastomoses such as coronary grafts through it or during an incision to expose the aortic valve. Screening therefore must precede surgical manipulation of the aorta. Detection of atheroma, however, cannot in its own right, prevent dislodgement of atheroma; prevention requires an alteration of the operation by the surgeon in some way in order to avoid dislodgement of atheroma. Therefore, screening of the aorta is an important adjunct to surgery.

2. Patients and methods

A single surgeon experience of 1687 cardiac surgery patients from 1996 to 2005 was used, where 1455 patients had undergone intraoperative ultrasound examinations as part of routine intraoperative management. A prospectively collected database of 591 of these patients from June 2001 until March 2004 containing atheroma prevalence was analysed.

A high frequency ultrasound probe such as a 15 MHz linear array probe and Sonos 5500 machine (15L-Philips, Andover, USA), was immersed in a custom sterile plastic sheath (Fairmont Medical Products, Bayswater, Australia) with sterile water or saline sufficient to fully immerse the probe.

2.1. Statistical analysis

Continuous variables were expressed as mean ± standard deviation and Fisher exact test using SPSS 13.0 (Chicago, IL). Significance if P < 0.05.
3. Description of systematic examination

3.1. Recommended equipment

A high frequency linear array ultrasound handheld probe with a frequency of 8–12 MHz is ideal, and should also be able to be immersed in fluid without damage.

3.2. Classification of aorta and atheroma

We refer to the proximal and mid descending aorta as the zones 1–3, the proximal and distal aortic arch as zones 4–5 and the proximal descending aorta as zone 6 [2]. The hand held ultrasound probe provides excellent imaging of zones 1–4, supplemented by transoesophageal echocardiography imaging zones 5–6.

3.3. Study views

Ten standard views are obtained in all patients and two supplementary views are obtained in some patients (Fig. 1). It is important to closely note the position of the probe foot plate and the angle of the handle to appreciate how to achieve these views. The probe should first be positioned as demonstrated on the heart image, and then fine adjustment made whilst viewing the image on the echocardiography machine in order to replicate the view as illustrated.

3.3.1. AV LAX: Longitudinal view of the aortic valve

The probe is placed obliquely over the right ventricular outflow tract in a line connecting the apex of the left ventricle and the ascending aorta. In this way, the aortic valve as viewed in a longitudinal manner and a good appreciation of the relationship between the dimension of the sinotubular junction and the aortic valve annulus is appreciated.

3.3.2. RCA SAX: Short axis of the right coronary artery

The probe is moved from the right ventricular outflow tract to the atrioventricular groove between the right atrium and the right ventricle. The probe itself is rotated anticlockwise by about 70°, displaying the right coronary artery in cross section. The probe is then moved progressively inferiorly. Motion artefacts can be compensated for by freezing the image and scrolling back, frame by frame.

3.3.3. LMCA SAX: Short axis of left main coronary artery

Continued angulation of the probe towards the left passes beyond the division of the left main coronary artery into the left anterior descending artery superiorly and circumflex artery inferiorly. Care should be taken not to exert excessive pressure on the pulmonary artery.

3.3.4. LAD/Cx SAX: Short axis of LAD and circumflex coronary arteries

Continued angulation of the probe towards the left passes beyond the division of the left main coronary artery into the left anterior descending artery superiorly and circumflex artery inferiorly. Care should be taken not to exert excessive pressure on the pulmonary artery.

3.3.5. AV SAX: Short axis of the aortic valve

The probe is positioned over the distal right ventricular outflow tract with angulation sweeping inferiorly to superiorly.

Aortic anatomy The aorta is generally more easily assessed in short axis view. The aorta does not adopt a straight line, but is continuously curved from the aortic valve to the descending aorta. Consequently some care needs to be taken ensuring that the probe remains at right angles to the ascending aorta at all times, in order to obtain an accurate short axis view.

3.3.6. Z1 SAX: Short axis Zone 1 aorta (proximal ascending aorta)

The aorta should appear entirely circular.

3.3.7. ZZ SAX: Short axis Zone 2 aorta (mid ascending aorta)

This portion of the ascending aorta usually lies in a direct superior/inferior direction, and so the probe is generally horizontal in order to image this at 90°.
3.3.8. Z3 SAX: Short axis Zone 3 aorta (distal ascending aorta)

The probe is now angled towards the left and inferior to the horizontal in order to transect the distal ascending aorta at 90°. The anatomical boundary between the distal ascending aorta and the proximal arch is marked by the pericardial reflection. This point is very easily identified with cardiac surgery since the thymus is divided and the pericardial attachments to the aorta are usually divided prior to cannulation.

3.3.9. Z4–5 LAX: Long axis of the aortic arch

The aortic arch continues in a leftward direction, but is then angled very steeply posteriorly. Generally it is not possible to obtain an image at right angles to this vessel since the sternum and the mediastinal structures will impede the probe handle. Consequently a longitudinal view is obtained with superior and inferior walls being imaged by sweeping the probe back and forth.

3.3.10. Cerebral vessels

The probe is now moved slightly more superiorly and angled sharply superiorly. Thus, the ultrasound passes superior to the aortic arch and engages the cerebral vessel branches.

3.4. Supplementary views

3.4.1. LMCA LAX: Longitudinal axis of the left main coronary artery

The probe is positioned in a transverse direction, and part of the probe is lying across the pulmonary artery and the other part across the aorta. The left anterior descending artery continues in the same direction and the circumflex artery then diverges inferiorly quite sharply.

3.4.2. RCA LAX: Longitudinal axis of right coronary artery

The probe is placed directly over the right coronary artery in a longitudinal orientation. It needs to be angled quite steeply, as the right coronary artery will arise at right angles to the aorta and travel directly anteriorly before adopting a sharp curve in the atroventricular groove between the right atrium and right ventricle, and then travels in a directly inferior direction. Colour flow Doppler interrogation can demonstrate antegrade flow in this vessel where there may be concern regarding occlusion by an aortic valve prosthesis.

3.4.3. Miscellaneous

A wide variety of alternative views are possible. A lower frequency probe will allow good examination of the mitral valve using AV LAX view. Good transverse imaging of the left ventricle is possible by placing the probe at right angles to the axis of the left ventricle and sweeping towards the apex. Excellent views of the interatrial septum are possible by placing the probe longitudinally on the roof of the left atrium between the aorta and superior vena cava.

4. Results

A single surgeon experience from 1996 to 2005 of 1687 cardiac surgery patients is reported, where there were 1455 (86%) intraoperative ultrasound examinations. Coronary surgery 1214 (72%), valve surgery 369 (22%), aortic surgery 30 (2%), congenital surgery 74 (4%) and reoperations 105 (6%). Neurological complications included stroke 13 (0.8%), TIA 2 (<0.1%), confusion 56 (3%), coma 24 h 8 (0.5%). In 591 patients recorded in the custom database, age 66±0.5 (25–93) years, 69% males and body surface area 1.9±0.2 m². NYHA class III and IV, 69%, and coronary surgery 77%. A variety of echocardiography machines and probes were used, but predominantly the Sonos 5500 and 15 MHz linear array probe (Philips, Andover, USA).

The incidence of aortic atheroma according to aortic region is listed in Fig. 2. The prevalence of atheroma increased with distance from the aortic valve (P<0.001). The overall incidence of moderate or severe atheroma in any part of the thoracic aorta increased with age (P<0.001), see Fig. 3. The incidence for patients <50 years was very low; however, moderate or severe atheroma somewhere in the thoracic aorta was present in the majority of patients over the age of 60 years. Moderate or severe atheroma in ascending aorta or proximal arch (zones 1–4), where direct aortic manipulation normally occurs, was 29% for those aged 70–79 years and 34% for those more than 80 years old.

5. Discussion

We describe a standardised intraoperative ultrasound examination of the aorta and proximal coronary arteries...
that may be used routinely during cardiac surgery procedures.

Clinical stroke occurs postoperatively in 1% to 3% of patients who have coronary artery bypass operations [3–7]. Neuropsychological dysfunction, representing subclinical organic brain injury, is much more common than stroke and is reported in 20% to 60% of patients [8,9]. Much of this brain injury is believed to occur as a result of atheroembolism of the brain caused by dislodgment of aortic atheroma during surgical manipulation of the aorta [10–12]. The key events are aortic cannulation and the application or removal of the aortic clamp.

With the exception of intra-aortic balloon pump use, most aortic manipulation occurs in aortic zones 1–4, such as aortic cannulation, clamping, proximal anastomoses and aortic valve exposure incisions. This area of the aorta represents the area imaged by intraoperative ultrasound of the aorta using a hand-held probe. The locality of atheroma is easily appreciated since it is present where the probe is.

The relationship between aortic manipulation and stroke was illustrated by Calafiore in 2002 [6]. The data from 4875 patients undergoing coronary surgery, were associated with stroke rates of 2.3%, 1.2%, 1.1% and 0.2%, respectively, with lesser aortic manipulation. Similarly, we found a reduction in postoperative neurocognitive dysfunction [13,14].

We compared the accuracy of manual (digital) assessment of the aorta for atheroma, known to be present by a combination of epiaortic ultrasound and transoesophageal echocardiography and found this method able to detect only 50% of moderate or severe lesions [1].

The incidence of moderate or severe atheroma in zones 1–4, where direct aortic manipulation normally occurs, was 29% for those aged 70–79 years and 34% for those more than 80 years old. This would suggest a high frequency of clinically important atheroma being present, that may require some alteration to the operation to avoid direct manipulation of atheroma, in the elderly cardiac surgical patient of a typical Western country practice.

We argue that the presence and locality of aortic atheroma should be routinely examined (using ultrasound) prior to any aortic manipulation being performed; and if atheroma is detected, then avoidance of this atheroma should be attempted.

Acknowledgments

Illustrations by Mr David Auld, statistical analysis by Prof John Ludbrook and the anaesthetic and nursing staff of Royal Melbourne Hospital. The full manuscript is available at www.heartweb.com.au.

References


ICVTS on-line discussion A

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doi:10.1510/icvts.2006.134296A

eComment: Congratulations for this excellent and coherent clinical work [1]. Neurological complications during/after cardiac surgery can be devastating and can completely cancel all benefits of surgery for the patients affected. We must acknowledge the fact that the profile of patients referred to surgery is changing (and will continue to do so) towards older individuals with complex comorbidities. Therefore, we have to struggle to keep our results good. Work like yours demonstrates that atheromas do exist even when we do not suspect them and that knowing where they are is better than simply hoping to not hit them. The next step is of crucial importance: the adaptation of surgical strategy: consider an OPCAB procedure instead of the scheduled straight forward pump run, consider alternative strategies for the proximal anastomosis and/or for the whole revascularization or for the scheduled valve procedure. I hope you will catch up with a following paper based on this vast and profound experience in which you could show the impact of the ultrasound findings on your surgical strategy.

References