BJA

British Journal of Anaesthesia, 115 (5): 708–15 (2015)

doi: 10.1093/bja/aev343
Cardiovascular

CARDIOVASCULAR

The effect of aorta unfolding and remodelling on oesophageal Doppler readings as probe depth is varied

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Abstract

Background: The thoracic aorta elongates and unfolds with advancing age. Lateral displacement and tortuosity of the descending part may affect oesophageal Doppler monitoring (ODM) readings because probe alignment becomes slanted. This investigation aimed to relate aortic displacement as it appears on the chest radiograph with variations in ODM readings as the probe is inserted to different depths.

Methods: In anaesthetized patients a series of three to five ODM stroke volume (SV) readings were obtained at insertion depths of 35–45 cm during stable haemodynamics. The coefficient of variation (CV=standard deviation/mean %) was calculated. The degree of descending aorta unfolding was measured by (i) lateral displacement (LD), that is, the difference in the maximum and minimum distances between the midline and para-aortic line; and (ii) curvature angle (CA), the angle formed by a tangential line from the intersection of the para-aortic line and the diaphragm to its curve with the vertical line.

Results: Data from 70 patients were analysed. The median CV of SV readings was 14% (range 4–48). Variation between ODM readings, shown by the CV of SV readings, increased linearly with aortic unfolding: R^2=0.44 for LD and R^2=0.60 for CA. Patients with a CA ≤15° were younger and had significantly lower CVs of ODM readings than those with a CA >15° (P=0.001). Age and hypertension was associated with increased CA.

Conclusions: Increased lateral displacement and tortuosity of the descending aorta reduces the reliability of ODM measurements as probe depth is varied, especially with aging.

Key words: aortic unfolding; oesophageal Doppler; stroke volume

Oesophageal Doppler monitoring (ODM) provides continuous and minimally invasive cardiac output (CO) readings in clinical anaesthesia and intensive care settings.[1 2] Its use provides a more comprehensive haemodynamic assessment and thus can be used to guide individualized goal-directed fluid management in major surgery.[3] Oesophageal Doppler has been shown to closely agree with pulmonary artery catheter (PAC) with respect to its ability to follow relative changes in CO.[4] It is safer and easier to use in those patients in which the risk of insertion of a PAC is difficult to justify. There is growing evidence that high-risk surgical patients treated under guidance of ODM have improved outcomes in terms of shortened length of hospital stay and reduced postoperative morbidity.[3 5–7] ODM in 2011 received National Institute for Health and Clinical Excellence (NICE) endorsement for intra-operative fluid optimisation,[8] and this has boosted its widespread use in certain types of surgical patients receiving general anaesthesia.

The ODM technique relies on the Doppler probe lying parallel, when in the oesophagus, with the adjacent descending thoracic

Accepted: July 14, 2015

Editor's key points

- Accurate use of the oesophageal Doppler monitor (ODM) requires the probe to be parallel with the aorta.
- If the aorta is tortuous, the alignment between the ODM and aorta may vary according to the depth of probe insertion.
- This study assessed the accuracy of ODM readings and whether aortic morphology could be predicted from chest X-ray appearances.
- The degree of aortic unfolding could be assessed using chest X-ray and was associated with increasing variability in stroke volume assessed by ODM.
- In patients with marked aortic curvature, ODM readings may be unreliable, as they vary according to the depth of probe insertion.

aorta. However, this is not always the case, and it is well recognized by ODM users that probe depth adversely affects the repeatability of its readings. The manufacturers recommend maintaining a constant probe depth, but this is not always possible because of the need to frequently refocus the probe, especially during abdominal surgery.

With advancing age, the thoracic aorta loses its elasticity and expands both in cross-sectional area and length.[9] To accommodate the extra length within the thorax, the aorta unfolds from its central position lying in front of the spine to a more lateral position. The descending aorta takes up a more left lateral position that is seen on chest radiographs as lateral displacement within the heart shadow. However, to exit the thorax, the aorta must pass through the diaphragm in front of the spine, and this results in the lower segment of the descending aorta transversing back to the centre, which is seen on the radiograph as a curvature. Radiological studies have shown that the thoracic aorta becomes tortuous, enlarged and unfolded with aging and disease.[10 11] Unfolding may change the alignment between the oesophagus and descending aorta, because the descending part moves left laterally and then curves back to exit the thorax. Therefore, unfolding may also change the insonation angle made by an ODM probe, leading to altered profile height and flow velocity in its Doppler scan. Most morphological assessments of thoracic aorta unfolding and remodelling of the descending part use advance imaging techniques, such as computerized tomography and magnetic resonance, which are often not available in surgical patients. But aortic unfolding and its effect on the descending thoracic part can also be assessed more simply by inspection and measurements of the descending aorta on the preoperative erect posteroanterior (PA) chest radiograph, especially with modern digital images.

The aim of the present investigation was to evaluate the effect of unfolding of the descending thoracic aorta on ODM readings during surgery as probe depth is varied. Unfolding was quantified on chest radiographs by lateral displacement and curvature angle of the aorta, which are described.

Methods

Patients

The present study was approved by the Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee. Adult patients, ASA I, II or stable III, scheduled for elective surgery were recruited at the Prince of Wales Hospital (Hong Kong) between October 2013 and November 2014. Exclusion criteria included patients with arrhythmia, implanted pacemaker, aortic aneurysm and oesophageal or thoracic disease causing morphological changes, such as scoliosis, that may interfere with probe positioning. All potential risks and procedures of the study were explained to the patient and written informed consent was obtained. The study was conducted in conformity with the principles of the Declaration of Helsinki.

Equipment

The CardioQ (Deltex Medical Ltd, Chichester, UK) ODM consists of a portable point-of-care unit with screen display and probe cable. The disposable probe has two piezoelectric crystals, transmitter and receiver embedded into its tip and angled at 45°. The probe is inserted via the mouth or nose and advanced into the lower oesophagus where it insonates blood flow in the descending thoracic aorta. From the Doppler shift signal, flow velocity is generated. A real-time velocity–time waveform is displayed on the CardioQ screen and stroke distance calculated.[4] Stroke volume (SV) is then calculated from the product of stroke distance and a derived constant based on the cross-sectional area of the descending aorta, insonation angle (i.e. 45°) and split ratio (i.e. proportion of blood flow to the lower body).[12] The cross-sectional area of the descending aorta is derived from a propriety nomogram that uses body surface area and age. CO is calculated by multiplying SV by heart rate. Two assumptions are made: (i) that the oesophagus and the descending aorta are parallel and (ii) that the angle between the ultrasound beam and blood flow is constant, at 45°.

Study protocol

The CardioQ probe was inserted via the nose shortly after induction of general anaesthesia. Once the patient's haemodynamics (i.e. heart rate and blood pressure) were stable, the probe was rotated to obtain an optimum Doppler flow signal. A flow profile that had a well-outlined triangular shape with clear beginning and ending, a well-formed crescent of higher intensity signals and was of maximum detectable peak velocity was considered optimal. The ODM probe has three depth markings at 35, 40 and 45 cm and these were used to guide probe position. Measurements were performed at 2–3 cm distance intervals over a 10 cm range from 35 to 45 cm. All the measurements were completed within a 2–3 min period of stable haemodynamics and before surgery started. A series of up to five SV measurements was used to assess reading variability. However, sometimes it was impossible to detect acceptable flow profiles over the whole 10 cm range and the number of readings was limited. The minimum number of readings accepted was three. Data were saved as screenshots and downloaded to a USB memory stick for analysis.

Radiographic assessment

The digital image of the patient's preoperative erect PA chest radiograph was retrieved from the clinical management system of the Prince of Wales Hospital. To quantify the extent of remodelling of the descending thoracic aorta, two indices were measured from the radiograph, lateral displacement (LD) and curvature angle (CA). The left lateral edge of the descending thoracic aorta can be visualized easily on a well-exposed PA digital radiograph as the para-aortic line. (i) Using computer measurement tools, perpendicular lines are drawn between the para-aortic line and a vertical line drawn along the spinal column (Fig. 1, left). Maximum and minimum lateral distance lines are plotted and LD is