

Diagnostic accuracy of modified transoesophageal echocardiography for pre-incision assessment of aortic atherosclerosis in cardiac surgery patients

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Key points

- Perioperative stroke during cardiac surgery is often caused by emboli arising from atherosclerosis in the AA, as this is where cannulation and clamping occurs.
- EUS of the AA may be used to detect atherosclerosis before cannulation but can only be applied during surgery.
- A-View device allows TOE to be used to make an assessment of aortic atheroma before sternotomy.
- TOE using the A-View device had a high negative predictive value in excluding relevant aortic atheroma before sternotomy.

Background. Epiaortic ultrasound scanning (EUS) is regarded as the reference standard for detecting atherosclerosis in the ascending aorta (AA). Combined with appropriate surgical modifications, EUS use can significantly reduce the incidence of postoperative stroke when detecting severe AA atherosclerosis. A recently introduced modification of conventional transoesophageal echocardiography (TOE), known as the A-View method, has proven capable of inspecting the distal AA. The objective of this study was to quantify the diagnostic accuracy of modified TOE in assessing atherosclerosis of the distal AA.

Methods. After approval by the institutional medical ethical committee and after obtaining written informed consent, 465 consecutive patients above 65 yr old, undergoing elective cardiac surgery with a median sternotomy, were included. The study followed a cross-sectional diagnostic design. All consecutive patients underwent modified TOE followed by EUS (reference standard) to assess the severity of distal AA atherosclerosis. We constructed contingency tables to compare the presence (and severity) of atherosclerosis, detected by the two techniques.

Results. The positive predictive value of modified TOE for the detection of clinically significant atherosclerosis was 67%, and the negative predictive value was 97%. The sensitivity was 95% and the specificity was 79%. One patient suffered a pulmonary haemorrhage, although he recovered without further sequelae. We did not observe any clinical significant haemodynamic or ventilatory effects.

Conclusions. The high negative predictive value and sensitivity show that modified TOE yields adequate diagnostic accuracy for excluding clinically relevant aorta atherosclerosis without significant cardiopulmonary side-effects, provided that the A-View catheter is introduced carefully.

Keywords: brain, ischaemia; embolism, thromboembolism; monitoring, echocardiography; surgery, cardiovascular

Accepted for publication: 8 March 2010

Each year, about 1 million patients worldwide undergo cardiac surgery. One of the most severe complications after cardiac surgery is ischaemic stroke. The overall incidence of major ischaemic stroke after cardiac surgery is about 3%, accounting for 20% of postoperative deaths.^{1–5} Postoperative stroke is often caused by emboli arising from atherosclerosis in the ascending aorta (AA), as the AA is where cannulation and clamping takes place.^{2–4}

Epiaortic ultrasound scanning (EUS) of the AA is a safe and useful method for detecting atherosclerosis in patients undergoing cardiac surgery. Combined with appropriate modifications of the operative technique based on EUS findings, most notably less manipulations of the atherosclerotic aorta, the use of EUS can effectively reduce postoperative incidence of stroke when severe AA atherosclerosis is present.^{6–10} Although it is not widely used, EUS is considered the gold

standard for detecting atherosclerosis in the AA in real time.^{11–14} However, EUS can only be applied during surgery, that is, after sternotomy. If the atherosclerosis turns out to be more severe than anticipated, decisions regarding possible changes in surgical strategy have to be made at a relatively late stage. It is preferable that such decisions can be made before operation, that is, before the sternotomy.¹⁵

Transoesophageal echocardiography (TOE) is a widely used imaging modality which enables evaluation of the extent of atherosclerosis in the thoracic aorta before the sternotomy. However, assessment of the distal AA using TOE is disturbed by the interposition of the air-filled trachea between the oesophagus and the AA (the so-called ‘blind spot’).¹⁶ Recently, the A-View (aortic view) method, a modification of conventional TOE, was introduced in order to overcome this limitation.^{17–19} The A-View method uses an intratracheal balloon (the A-View catheter developed by Cordatec Inc. in Zoersel, Belgium) filled with saline to replace the air in the distal trachea and left main bronchus. It therefore becomes possible to assess the distal AA and aortic arch for the presence and severity of atherosclerosis before cardiac surgery, which provides the surgeon with 30–45 min of additional planning time.^{17 18}

The question arises as to whether modified TOE (the A-View method) used before the sternotomy and the corresponding changes in the surgical strategy yield better patient outcomes compared with surgery using EUS. Obviously, this requires a direct comparison of both strategies in a randomized follow-up study. This would have to include a large number of subjects due to the relatively low incidence of postoperative stroke. Presently, it is too early for such trials. Similar therapies and diagnostic devices should undergo a rigorous and phased evaluation before their practical introduction.^{20–24} The first technical and safety evaluations showed that modified TOE is indeed capable of visualizing the distal AA and does not lead to unexpected complications due to the device.¹⁷ Subsequently, a diagnostic (cross-sectional) accuracy study—in this case, directly comparing the results of each patient after both modified TOE and EUS—is commonly executed. This was the purpose of the present study: to determine the extent to which modified TOE can discriminate between cardiac surgery patients with and without aortic atherosclerosis, using EUS as the reference standard.

Methods

Study population

After approval by the institutional medical ethical committee and after written informed consent was obtained from all participants, 465 patients above 65 yr of age who were undergoing elective cardiac surgery involving a median sternotomy were included in the study. All eligible patients, that is, those who fulfilled the inclusion and exclusion criteria and for whom (according to the operation schedule) an operator was available, were studied consecutively. Patients who underwent surgery between May 2006 and December 2008 were included. Patients with contraindications to TOE

(oesophageal pathology and hiatus hernia) or contraindications for modified TOE (i.e. severe chronic obstructive pulmonary disease and tracheal stenosis) were excluded.^{17 18}

This multicentre study was performed in one academic centre (University Medical Center Utrecht in Utrecht, The Netherlands) and two general university-affiliated teaching hospitals (Isala Clinics in Zwolle, The Netherlands, and Amphia Hospitals in Breda, The Netherlands). In each participating centre, there were one or two anaesthesiologists trained *a priori* to use modified TOE. If a patient at one of the centres was considered eligible and thus included in the study, but one of these two anaesthesiologists could not be undergoing the surgery, the patient was excluded (see below). The study was conducted in accordance with the moral, ethical, and scientific principles governing clinical research as set out in the Declaration of Helsinki (1989) and Good Clinical Practice.

Design and measurement

The study followed a cross-sectional diagnostic design. All patients underwent the same systematic work-up including modified TOE followed by EUS as the reference standard (no partial or differential outcome verification).^{25–27} Heart rate, mean arterial pressure, oxygen saturation, and end-tidal CO₂ were continuously recorded. The study was designed as a purely diagnostic study, and no interventions were performed based on the results of the test being studied (modified TOE). All treatment decisions were based upon current guidelines and routine clinical care practice.

The A-View method

The A-View method has been described extensively.^{17 18} After induction of anaesthesia and intubation of the trachea, but before surgical incision, the anaesthesiologist introduced the A-View catheter through the tracheal tube and into the left main bronchus. After checking the correct position of the catheter by auscultation and interrupting ventilation, the balloon was filled with 20–50 ml of sterile saline. During a short period of apnoea (1–2 min), modified TOE was performed by retracting the TOE probe (S7-2 omniplane TOE transducer, developed by Philips in Eindhoven, The Netherlands—a transoesophageal phased array transducer with 64 elements, with a 7 to 2 MHz extended operating frequency range and with a field of view of 90°) from the mid-oesophageal aortic short-axis view^{18 28} until the distal AA and aortic arch with its side branches were seen (20–30 cm from the incisors) (Fig. 1). To obtain optimal view, the depth for imaging the AA was adjusted between 8 and 10 cm. Whenever necessary, lateral flexion of the tip of the echo-probe was used to improve imaging quality. After completion of the investigation, saline was aspirated from the A-View catheter, the catheter was removed, and ventilation resumed. After removal of the A-View catheter, the tip was inspected for the presence of blood. If blood was present on the catheter, bronchoscopy was performed to detect possible side-effects caused by the A-View catheter. In

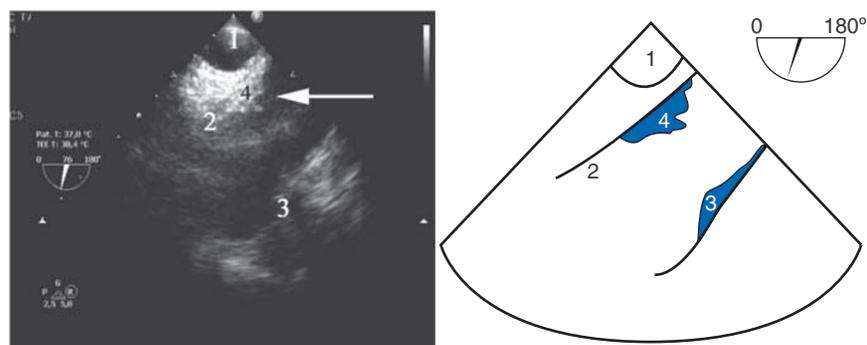


Fig 1 Distal, long-axis view of the AA as imaged with modified TOE, with plaque formation on the posterior and the anterior wall (1, trachea; 2, posterior wall of distal AA; 3, anterior wall of distal AA; 4, mobile protruding atheroma indicated by the arrow). (Reprinted with permission from Nierich and colleagues.)¹⁸

each participating centre, before the EUS was performed, modified TOE was performed and interpreted online by one of the two attending anaesthesiologists (observers) trained in this method. This ensured that the modified TOE result was not influenced by the results of the reference test (EUS), since the EUS result was unknown at that point.

The presence and severity of atherosclerosis of the distal AA were documented online by the observer (the attending anaesthesiologist) using a five-point scale (Grade I, normal aorta; Grade II, extensive intimal thickening; Grade III, protruding atheroma (<5 mm); Grade IV, protruding atheroma (>5 mm), and Grade V, mobile plaques).²⁹ Before the study, we defined, in accordance with Katz and colleagues,²⁹ the presence of evident AA atherosclerosis as Grades III, IV, and V and the absence as Grades I and II. To describe the location of AA atherosclerosis, the AA was divided in two segments: proximal (from the aortic valve until the right pulmonary artery) and distal (from the right pulmonary artery until the innominate artery).

Epiaortic ultrasound scanning (reference test)

EUS was performed after sternotomy and the opening of the pericardium, and before aortic cannulation by the cardiac surgeon. An epiaortic probe (L15-7io epiaortic probe, developed by Philips in Eindhoven, The Netherlands—a broadband compact linear array transducer, with a 15 to 7 MHz extended frequency range and a field of view of 8° of trapezoidal imaging) was placed on the AA, and short- and long-axis views of both the entire (proximal and distal) AA were systematically obtained. The EUS probe used contains a built-in standoff that allows high-resolution imaging of both the anterior and the posterior wall of the AA. EUS was performed by the attending cardiac surgeon without knowledge of the results of the modified TOE. The EUS images were interpreted by the same anaesthesiologist who interpreted the modified TOE. To enhance the direct comparison required for the diagnostic accuracy study, the EUS result for aortic atherosclerosis was coded in accordance with the same five-grade scoring categories that were used for modified TOE.

Outcome

The primary outcome of our study was the presence or absence of clinically significant atherosclerosis (Grades III–V) in the distal AA as determined by EUS. Secondary endpoints included the degree of aortic atherosclerosis according to the above-defined five-point scale, and complications due to the use of the A-View catheter, notably cardiopulmonary side-effects (such as tachycardia, hypoxaemia, and hypercarbia). Damage as a result of the placement of the A-View catheter in the trachea and main left bronchus was actively monitored and recorded.

Statistics

Using standard methods for power calculations of diagnostic accuracy studies, we estimated *a priori* that to find a sensitivity (i.e. the true positive rate or the proportion of subjects with clinically significant atherosclerosis who indeed are graded as such with a positive test result by the A-view method) and a specificity (i.e. the true negative rate or the proportion of subjects without clinically significant atherosclerosis who indeed are graded as such with a negative test result by the A-view method) of 90% for the detection of atherosclerosis of modified TOE, and to be able to show that the sensitivity is at least 80% (i.e. a standard error of 5%), 120 patients with clinically relevant atherosclerosis would be needed, using an α of 0.05 and a β of 0.1. The frequency of clinically significant AA atherosclerosis (Grades III–V) among patients undergoing cardiac surgery is estimated at about 30%. The total number of patients to be included should then be at least $120 \text{ (cases)} / 0.3 \text{ (incidence of atherosclerosis)} = 400$. Therefore, inclusion of 465 patients (as in our study) would suffice for estimation of the hypothesized diagnostic accuracy parameters.

We constructed contingency tables to compare the presence (and severity) of AA atherosclerosis based on modified TOE with the results from EUS (reference test). We estimated the positive and negative predictive values, sensitivity and specificity, and both likelihood ratios with 95% confidence

intervals. This was done for each possible threshold between the five grades of aortic atherosclerosis.

Before operation, a total of 136 of the 465 eligible patients had values missing for one or more of the variables. This was mainly due to a missing modified TOE and EUS result because one of the trained anaesthesiologists was unable to undergo the surgery (Fig. 2). Data omission rarely occurs completely at random, but rather selectively (i.e. selectively missing data). Accordingly, it is now widely acknowledged in the methodological literature that simple complete case analyses actually lead to biased results.^{30 31} A comparison of characteristics between subjects with and without missing values is therefore always recommended to check whether missing data indeed was completely at random. We did so (Table 1) and we were pleased to see that there were only small differences between the completely observed subjects and the subjects with at least one missing value. However, they were still different to some extent, meaning that the subjects with missing data were not a random subset of those with fully observed data and vice versa. Simply excluding subjects with missing data would thus not solve a problem but create selection bias, as the 'intention to test' principle (in conformity randomized trials) is violated. Therefore, to conform to current guidelines,^{30 31} we rather multiply imputed data for all subjects with at least one missing value using the *aregimpute* function in R version 2.6.0.³²

For comparison purposes, we also performed a complete case analysis, the results of which can be found in the Supplementary Appendix.

Results

Figure 2 shows the flow chart of the 465 *a priori* eligible patients. The chief reason for missing imaging results was

logistics. No patients were excluded as a result of poor imaging quality with modified TOE.

The mean age of the 465 patients was 74 (range 65–88) yr. The study population consisted of 289 (62%) males and 176 (38%) females. One hundred and twelve patients underwent isolated coronary bypass surgery, 107 had valve surgery alone, 239 patients had combined bypass and valve surgery, and seven underwent other surgical procedures.

Modified TOE and EUS showed the presence of atherosclerosis in 135 patients and the absence of atherosclerosis in 256 patients. In 67 cases, EUS showed minimal atheroma, whereas modified TOE found high-grade atheroma, and in seven cases, EUS showed the presence of atherosclerosis, whereas modified TOE did not (Table 2). Therefore, the positive predictive value of modified TOE for the detection of clinically relevant atherosclerosis in the distal AA was 67%, and the negative predictive value was 97%. The sensitivity was 95% and the specificity was 79% (Table 2).

The modified TOE result overestimated the severity of atherosclerosis in 122 patients and underestimated the severity of atherosclerosis in 17 patients (Table 3). For true Grade I atherosclerosis, the modified TOE result was in 20% (37/187) Grade II and in 17% (32/187) above the threshold for our primary endpoint, i.e. Grades III–V. Therefore, for our primary outcome, we can consider 17% of the results to be false positives. When the true grade of atherosclerosis was Grade II, the modified TOE had a false-positive rate of 26% (35/136). For Grade III, the overestimation was 13% (16/122). Underestimation that changed the result (i.e. false-negative results) was found in 6% of the subjects (7/122) for Grade III. There were no misclassifications for Grades IV and V atherosclerosis (Table 3).

Figure 3 shows the receiver operator characteristic (ROC) curve of modified TOE for the detection of atherosclerosis

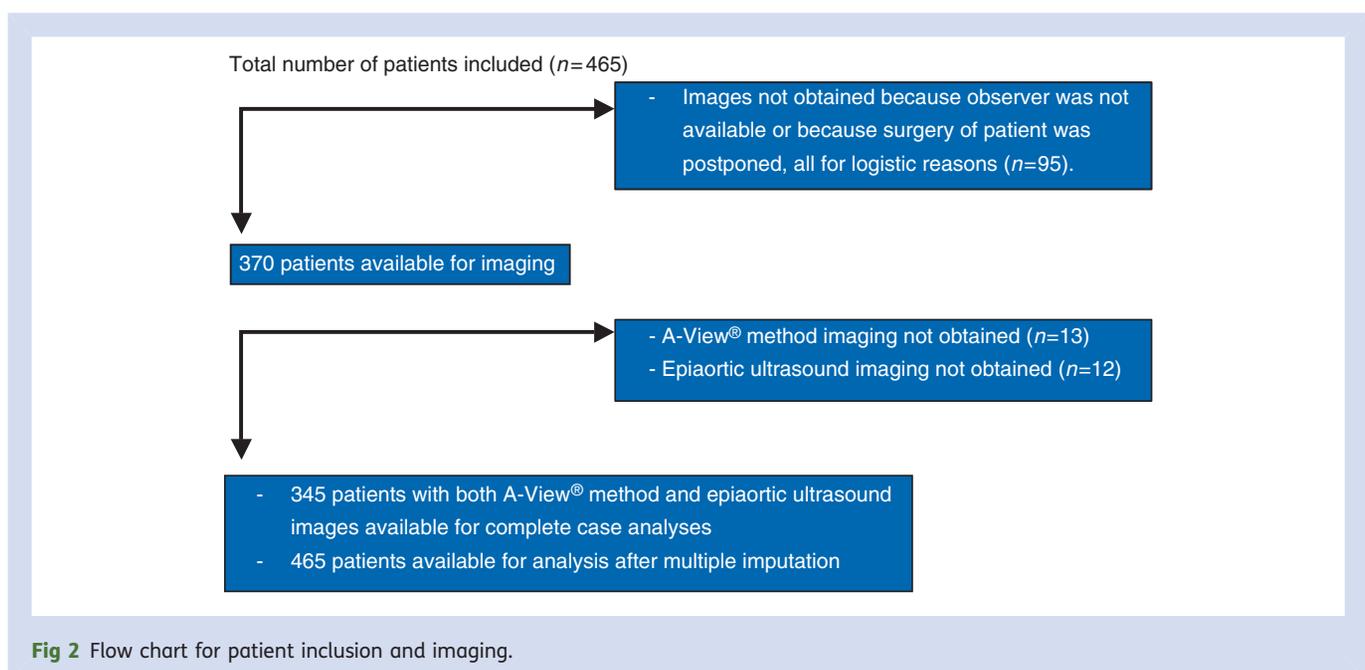


Table 1 Patient characteristics. Data are given as mean (sd or range) or number (%)

	Modified TOE and epiaortic ultrasound scanning images obtained (n=345)	Modified TOE or epiaortic ultrasound scanning images not obtained (n=120)	P-value
Male (%)	209 (60)	80 (67)	0.13
Age in years (range)	74 (65–88)	74 (65–88)	0.96
Height (cm) (sd)	171 (10.0)	170 (9.3)	0.39
Weight (kg) (sd)	79 (14)	80 (13)	0.45
Creatinine (mmol litre ⁻¹) (sd)	98 (52)	106 (59)	0.15
Chronic pulmonary disease (%)	46 (13)	21 (18)	0.16
Peripheral vascular disease (%)	44 (13)	13 (13)	0.55
Neurological dysfunction (%)	43 (13)	15 (13)	0.54
Hypertension (%)	171 (50)	53 (45)	0.20
Left ventricular function (%)			
>50%	195 (57)	61 (54)	0.68
30–50%	122 (36)	43 (38)	
<30%	23 (7)	10 (9)	
Recent myocardial infarction (%)	23 (7)	14 (12)	0.06
Diabetes mellitus (%)	79 (23)	23 (19)	0.65
Type of operation (%)			
CABG	91 (26)	21 (18)	0.007
Valve	85 (25)	22 (18)	
Combined	162 (47)	77 (64)	

Table 2 The presence (Grade III, IV, or V) vs absence (Grade I or II) of distal AA atherosclerosis visualized with modified TOE compared with the EUS result. Positive predictive value 67% (95% confidence interval=60–73%), negative predictive value 97% (95–99%), sensitivity 95% (92–98%), specificity 79% (75–84%), likelihood ratio of a positive test result=4.6 (3.7–5.7), and likelihood ratio of a negative test result=0.06 (0.03–0.13)

		Epiaortic ultrasound scanning		
		Presence	Absence	Total
Modified TOE	Presence	135	67	202
	Absence	7	256	263
	Total	142	323	465

Table 3 Severity of distal AA atherosclerosis visualized with modified TOE compared with the EUS result [Grade I, normal aorta; Grade II, extensive intimal thickening; Grade III, protruding atheroma (<5 mm); Grade IV, protruding atheroma (>5 mm); and Grade V, mobile plaques]²⁹

		Epiaortic ultrasound scanning				
		I	II	III	IV	V
Modified TOE	I	118	10	3	0	0
	II	37	91	4	0	0
	III	31	33	99	3	0
	IV	1	1	15	9	0
	V	0	1	1	2	6

in the distal AA for each possible threshold in Table 3. The area under the ROC curve was 0.89. By increasing the threshold for clinically relevant atherosclerosis in the distal AA from Grades III to IV, the positive predictive value increased from 67% to 92%, albeit at the cost of a reduction in the negative predictive value from 97% to 75% (Table 4).

Safety

During the intraoperative use of modified TOE, there were no changes in oxygen saturation [before (sd) 99 (1), after (sd) 98 (3)], the end-tidal CO₂ [4.2 (0.5), 4.8 (0.6)], the heart rate [66 (11), 68 (12)], or the mean arterial pressure [75 (13), 76 (12)]. In 10 patients (2.9%), there was blood on the catheter. Bronchoscopy revealed insignificant mucosal bleeding without any additional interventions needed on any of these patients. However, we observed one unexpected severe complication. In one patient, a massive pulmonary haemorrhage was observed after weaning of cardiopulmonary bypass. This patient was admitted to intensive care and ventilated for several days. The patient was later discharged from the intensive care unit and recovered without further sequelae.

Discussion

Modified TOE shows good accuracy for excluding the presence of clinically relevant distal AA atherosclerosis, as can be inferred from the high negative predictive value (97%)

and sensitivity (95%). As diagnostic tests by themselves do not improve patient outcome, but do so only via the treatment strategies that are chosen based on their results,³³ it would seem that planned surgery can safely proceed in the event of a negative result. If the result is positive for distal AA atherosclerosis, we recommend anticipating that changes to the surgical plan might have to be made to reduce manipulation of the AA. To confirm the presence of atherosclerosis, additional imaging of the distal AA using EUS could be an option.

Limitations of the study

The EUS result was interpreted by the same attending anaesthesiologist who interpreted the modified TOE result. Not blinding the EUS results from the modified TOE result could obviously have influenced the interpretation of the EUS images (known as incorporation bias). Therefore, to minimize

the potential for incorporation bias, the results of modified TOE were not communicated to the surgeon who actually performed the EUS.²¹ As a result, the surgeon did not actively search for any atherosclerotic plaques that were detected using modified TOE. Moreover, we found that modified TOE detected a higher degree of atherosclerosis in 122 patients rather than vice versa, which also reduces the likelihood of incorporation bias. If the effect of incorporating the knowledge of the modified TOE result into the EUS reading would be large, one would expect the result of the EUS to more frequently resemble the modified TOE result. Although we are fully aware that the presence of incorporation bias cannot be ruled out completely, we believe that the effect of not blinding the EUS image from the modified TOE result was relatively small.

Furthermore, we used EUS as a reference standard rather than modern magnetic resonance imaging (MRI) and computer-aided tomography (CT) scanners, because EUS is currently the most widely used reference standard for this disorder. MRI and CT have limited application and availability in routine care of cardiac surgery patients. Even more importantly, they are not capable of providing real-time images of the AA to direct immediate changes in surgical strategy.

Limitations of modified TOE

Not all of the subjects included underwent all measurements. The main reason for this was changes to the operation schedule which led to unavailability of the observer trained in modified TOE. The characteristics between patients with and without missing modified TOE or EUS results were only slightly different. The best course of action in such cases is not to exclude patients with missing data but to multiply impute the missing data, which we did in this case. However, as we realized that this might seem counter-intuitive, and given that the differences between the subjects with missing vs observed data were only minor, we also performed a complete case analysis for the purposes of comparison. These results are presented in the Supplementary Appendix. It did not change the results or inferences of the imputed analysis, which indicates that both inferences are well founded.

When introducing a new observer-dependent diagnostic test, it always takes time to develop the skills needed to acquire and interpret its results. Before patient inclusion started, the participating observers received additional training on the modified TOE (5–10 cases). We assume that there

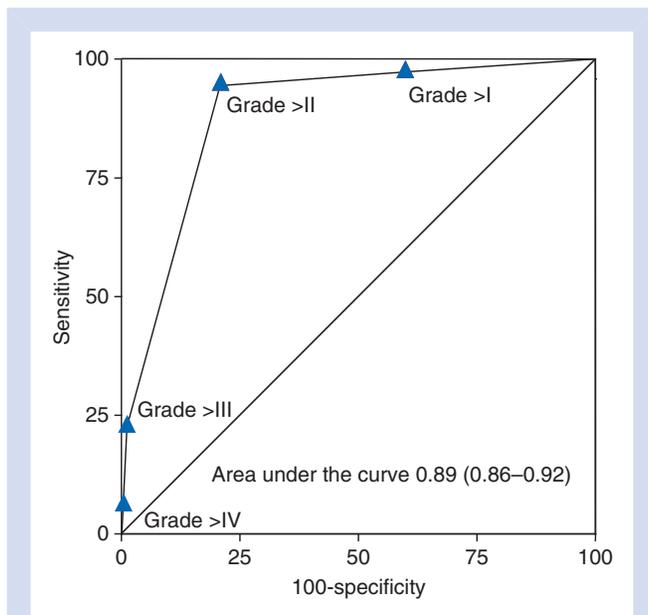


Fig 3 ROC curve of the modified TOE result for the detection of atherosclerosis in the distal AA in patients undergoing cardiac surgery. Blue triangles represent the different threshold values (see Table 4 for the diagnostic accuracy parameters of each threshold).

Table 4 Diagnostic accuracy parameters of modified TOE compared with EUS for various thresholds expressed as percentage (95% confidence interval) (Fig. 3)

Threshold	Positive predictive value	Negative predictive value	Sensitivity	Specificity	Likelihood ratio of a positive test	Likelihood ratio of a negative test
Grade >I	42 (36–47)	98 (95–100)	98 (96–100)	40 (34–45)	1.62 (1.48–1.78)	0.05 (0.02–0.16)
Grade >II	67 (60–73)	97 (95–99)	95 (92–99)	79 (75–84)	4.58 (3.69–5.69)	0.06 (0.03–0.13)
Grade >III	92 (83–100)	75 (70–79)	23 (16–30)	99 (98–100)	25.2 (7.8–80.2)	0.77 (0.71–0.85)
Grade >IV	90 (71–100)	71 (67–75)	6 (2–10)	100 (99–100)	20.5 (2.6–160.1)	0.94 (0.90–0.98)

was a short and steep learning curve, since the A-View method is just an extension of conventional TOE with which anaesthesiologists have been familiar for years.

In 67 cases, modified TOE showed clinically relevant atherosclerosis of the distal AA which was not detected by EUS. This could be because the linear ultrasound beam of the epiaortic probe is smaller than the V-shaped TOE probe ultrasound beam. Therefore, modified TOE allows imaging of a larger part at once of the distal AA, which increases the chances of detecting atherosclerotic plaques. Furthermore, as the EUS probe is placed directly on the AA, there may be limited visualization of the anterior wall of the AA, despite the built-in standoff. Finally, due to the epicardial fold, imaging of the innominate artery and its surroundings is limited with EUS, whereas modified TOE is capable of imaging this region without difficulty. Since this region is favoured by atherosclerotic plaques, EUS may underestimate the presence and severity of atherosclerosis. Modified TOE overestimated the presence of atherosclerosis depending on the severity (grade) of atherosclerosis by 13–26%. For patients with a false-positive result, more careful surgical strategy would be used, which, while inaccurate, can hardly be considered harmful. Most changes in surgical strategy are small, for example, changing the cross-clamping site or cannulation site.

The strength of our study is that we performed a prospective study in which patients were consecutively selected based on their indication to undergo the index test (intention to test in practice), and all underwent the reference test irrespective (unselected) of and blinded from the modified TOE result.³⁴ Retrospectively, selecting study patients based on their 'true' presence or absence of the disease or only selecting those who completed the reference test commonly leads to the problematic and well-known partial and differential verification biases.^{25–27}

In contrast to previous studies that showed no unintended effects whatsoever,^{17 18} this study showed one patient who suffered a massive pulmonary haemorrhage. During introduction of the catheter, a higher than normal resistance was felt. After imaging was complete, the catheter was removed and a small spot of blood was seen on the catheter. Contrary to study protocol prescriptions, bronchoscopy was not considered necessary at that time. After weaning from cardiopulmonary bypass, massive pulmonary bleeding was noted. The bronchoscopy performed at that time revealed a small mucosal tear without active bleeding. The patient was admitted to the intensive care unit and remained there for several days with severe respiratory failure due to extensive clotting in the lungs. Fortunately, the patient made a full recovery without any further interventions and without further sequelae. The most likely explanation for this pulmonary haemorrhage is the (traumatic) introduction of the A-View catheter into the left bronchus, which made a small, bleeding tear during complete heparinization. In the patients for whom bronchoscopy was performed because of blood on the A-View catheter, there were only small mucosal bleedings. These did not require additional interventions. The use of bronchoscopy

is advised for all patients who undergo modified TOE, and certainly in those patients who show signs of (mucosal) tracheal or bronchial bleeding, that is, blood on the A-View catheter after removal from the trachea.

To conclude, modified TOE yields adequate diagnostic accuracy for excluding atherosclerosis of the distal AA without significant cardiopulmonary side-effects, provided that the A-View catheter is introduced carefully. The method can be used to guide surgical management in combination with EUS.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Conflict of interest

A.P.N. is a medical director of Cordatec Inc., Zoersel, the Belgium-based manufacturer of the A-View catheter.

Funding

The study was supported by a grant by ZonMw, the Netherlands Organization for Health Research and Development (project number 945-27-009).

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