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# Transoesophageal echocardiography in cardiac and vascular surgery: implications and observer variability

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Transoesophageal echocardiography (TOE) has gained widespread acceptance among cardiac anaesthetists as a tool to facilitate peri-operative decision-making. This observational study analyses the impact of TOE and its inter-observer variability on intra-operative patient management during cardiac and major vascular surgery. From June 1996 to December 1998, standardized reports were obtained from 11 anaesthetists in 1891 adult cardiac and vascular surgery patients undergoing routine biplane or multiplane TOE. Inter-observer variability and the difference between variables of interest were tested using the chi-squared test or factorial analysis of variance as appropriate. TOE examinations were performed before and after the operation; 1673 (88.5%) patients underwent cardiopulmonary bypass (CPB), and 218 (11.5%) patients had surgery without CPB, including 42 (2.2%) coronary revascularizations. In 923 patients (49%), TOE provided additional information that influenced the patient's therapy. In 968 patients (51%), TOE had only minor or no impact on clinical decision-making. In two patients (0.10%) the scheduled operation was not performed, and in another two patients the TOE examination led to major complications. Observer-dependent variables were: implications of TOE for intra-operative decision-making ( $P<0.0001$ ), estimation of image quality ( $P<0.0001$ ), pre-operative left ventricular fractional area change (FAC) ( $P=0.0026$ ), difference between pre-operative FAC and post-operative FAC ( $P=0.033$ ), and requests for supervision ( $P<0.0001$ ). There was no significant difference in the case mix between observers. TOE had an important impact on intra-operative patient management. Inter-observer variability was significant for several variables but not for the frequency of additional surgical procedures.

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Indications for transoesophageal echocardiography (TOE) in the peri-operative period in cardiac and non-cardiac surgery were classified by the Society of Cardiovascular Anesthesiology and the American Society of Anesthesiologists in 1996.<sup>1</sup> Since then, several papers dealing with the implications of the routine use of TOE in cardiac surgery<sup>2–7</sup> and in major non-cardiac surgery<sup>8–12</sup> have been published. Other studies have addressed the problem of adequate imaging and inter-observer variability<sup>13</sup> and the need for quality control when using TOE.<sup>14</sup>

The aim of the present observational study was to analyse the impact of TOE and its inter-observer variability on peri-operative patient management during cardiac and major vascular surgery.

## Methods

Intra-operative TOE is routinely performed at our institution by cardiac anaesthesia staff in the large majority of cases of cardiac surgery and major vascular (thoracic and abdominal aorta, carotid artery) surgery, except in patients with an overt contraindication and when a TOE probe is not available. Since June 1996, all anaesthetists performing peri-operative TOE have been asked to complete standardized report forms during the examination.

### *Anaesthesia and insertion of the TOE probe*

Patients were pre-medicated with oral benzodiazepines (flunitrazepam or midazolam). In the operating theatre,

anaesthesia was induced, the patient's trachea was intubated, and the lungs were mechanically ventilated. After insertion of a central venous catheter and a pulmonary artery catheter (if considered necessary), the latex-sheathed TOE probe was inserted, usually with an Esmarch manoeuvre or with the help of direct laryngoscopy if necessary.

### *TOE examination*

Examinations were performed by a staff anaesthetist who was supervising a resident in charge of routine anaesthesia. Two Hewlett-Packard machines (HP Sonos 1500; Hewlett-Packard, Andover, MA, USA), initially with a biplane and later a multiplane 5-MHz TOE probe, and a Vingmed machine (CFM 800; Vingmed Sound, Horten, Norway) with an omniplane 5-MHz probe were used. A thorough TOE examination was performed, including injection of an air-saline emulsion via the central venous catheter into the right atrium after a ventilator-stimulated Valsalva manoeuvre (application of positive end-expiratory pressure (PEEP) of 20 cm H<sub>2</sub>O, followed by release of PEEP and immediate injection of the emulsion) to detect or rule out a patent foramen ovale. Examinations were recorded on videotape according to the standard procedure. Less experienced observers had the opportunity to call for advice from a more experienced anaesthetist at any time. A cardiologist's help was available by means of a video line between the operating theatre and the TOE laboratory during daytime or by direct advice in the operating theatre.

### *Reporting, analysis of data and surgical consequences*

To ensure adequate quality, a TOE-database/reporting system was introduced in June 1996, and all staff cardiac anaesthetists were advised to complete reports during adult TOE examinations in the operating theatre. The number of reported examinations was compared with the number of effectively performed TOEs and calculated as a percentage of reported cases, based on comparison with a written list of all examinations.

Data collected in these reports included technique and ease of probe insertion. 'Easy' insertion was achieved when the observer was able to introduce the probe without effort and/or unexpected problems. Insertion was 'difficult' when additional manoeuvres were necessary (unplanned direct laryngoscopy, several trials of introducing the probe) and 'impossible' when introduction was not feasible with laryngoscopy and, therefore, without probable harm to the patient.

Subjective estimation of image quality was 'good' if endocardial borders could be visualized in all four segments of the left ventricular (LV) short-axis view; 'moderate' if sufficient information for clinical decision-making was achieved but all endocardial borders were not visible; and 'insufficient' if the observer was not able to see important

structures (e.g. the anterior and lateral walls of the left ventricle) because of bad image quality.

For evaluation of systolic LV function, global LV function was classified as 'normal' (fractional area change (FAC)  $\geq 50\%$ ), 'moderately impaired' (FAC 40–50%), or 'impaired' (FAC  $< 40\%$ ). Regional wall motion abnormalities (RWMA) were assessed by online estimation at mid-papillary-muscle level in short- and long-axis views, and in four-cavity view (horizontal and longitudinal views of the left ventricle), as proposed by the American Society of Echocardiography.<sup>15</sup> RWMA were reported if contractility decreased by two or more grades between two examinations (before and after cardiopulmonary bypass (CPB) or pre-operatively and intra- or post-operatively) according to Bergqvist and colleagues.<sup>16</sup> If a new RWMA was observed, an additional venous aorto-coronary bypass was performed if the operating surgeon considered it to be beneficial. When this was not feasible or not thought to be necessary, the insertion of an intra-aortic balloon pump (IABP) was considered.

FAC was assessed before surgical incision and after haemodynamic stabilization after CPB or after completion of the surgical procedure in operations without CPB.

Tests of the anatomy and function of cardiac valves, the test for patent foramen ovale, and evaluation of ascending, arch, and descending aortas were performed. Aortic plaques were classified according to Montgomery.<sup>17</sup> In case of plaques grade IV and V in the ascending aorta/aortic arch, surgeons modified their procedure by avoiding any trauma to the aorta whenever possible.

The need for supervision and/or for a cardiologist's advice and the subjectively single most important impact of the TOE examination on peri-operative patient management were also reported.

Categories for therapeutic consequences were: 'none' (if the entire TOE examination did not supply any additional information useful for patient management); 'surgery OK' (if the observer's assessment of cardiac function after surgery revealed no new RWMA after coronary artery revascularization procedures and normal function after valve repair or replacement); 'drugs/fluids' (if drug treatment and/or fluid therapy was changed or extended because of the TOE examination); 'change of surgical procedure' (if the planned surgical procedure had to be adapted according to a new finding in the TOE examination); 'new diagnosis' (if peri-operative TOE exhibited a previously unknown diagnosis, e.g. patent foramen ovale, subvalvular aortic stenosis, or new RWMA); or 'other.'

### *Evaluation of neurological outcome*

Neurological outcome was assessed clinically by staff members of the intensive care unit before the transfer of the patient to the ward. If focal or generalized neurological damage was suspected or overt during routine examination, a consultant neurologist was asked to confirm the diagnosis.

### Statistical analysis

Differences between observers and between variables of interest were analysed using the chi-squared test or with factorial analysis of variance as appropriate. *P* values of <0.05 were considered significant.

### Results

Between June 1996 and December 1998, a total of 1891 TOE reports were completed by 11 cardiac anaesthetists. In the same period, 2296 examinations were performed, resulting in an overall reporting performance of 82.4% (74.4, 90.4) (mean, 95% confidence interval) (Table 1). The percentage of reported TOE examinations varied significantly between observers ( $P<0.0001$ ).

The total number of cardiac and major vascular operations performed during this time was 2762, and the percentage of TOE examinations was 83% (81% for cardiac and thoracic aortic surgery, 85% for major vascular surgery).

**Table 1** Transoesophageal echocardiography (TOE) examinations performed and reported by 11 observers. \*Chi-squared=2390,  $P<0.0001$

Observer	Previous experience (no. of TOEs)	Examinations performed	Examinations reported	Per cent reported
A	>300	211	195	92.4
B	>300	177	176	99.4
C	>300	194	89	45.9
D	>300	519	430	82.9
E	>300	345	288	83.5
F	150–300	228	177	77.6
G	150–300	181	140	77.3
H	150–300	105	86	81.9
I	<100	106	105	99.1
K	<100	166	146	88.0
L	<100	64	59	92.2
Total		2296	1891	82.4*

The 11 cardiac anaesthetists who performed the examinations had various levels of experience in peri-operative TOE (Table 1). Five anaesthetists had performed more than 300 TOEs before the survey began; during this study, they accomplished 1178 (62.3%) of the reported examinations. Three anaesthetists who had previously performed 150–300 TOEs carried out 403 (21.3%) of the reported examinations. The remaining three anaesthetists, who had performed fewer than 100 TOEs, performed 310 (16.4%) of the reported examinations (Table 1).

### Probe insertion and complications

Ease and complications of probe insertion were reported from 1997 on, resulting in 1660 completed records: 1608 (97%) of the probe insertions were performed with a simple Esmarch manoeuvre, and 47 (2.8%) insertions were performed with direct laryngoscopy. Insertion was 'easy' in 1612 (97%) patients, 'difficult' in 26 (1.6%), and 'impossible' in five (0.3%). Complications of TOE were: arterial hypertension >30% of baseline value in 48 patients (2.4%), coughing in three patients (0.15%), tooth damage in two patients (0.1%), severe arrhythmia in one patient, hypopharyngeal perforation in one patient with Zenker diverticulum,<sup>18</sup> and a bleeding gastric mucosal lesion in one patient with previously unknown situs inversus abdominalis.

The complications required drug therapy in 27 (1.6%) patients, post-operative treatment by a dentist in two patients (0.1%), intra-operative gastroduodenoscopy and local treatment of a bleeding lesion in the patient with situs inversus, and immediate operation and prolonged treatment in the intensive care unit for the patient with the hypopharyngeal perforation.

**Table 2** Types of operation and therapeutic implications. \*Chi-squared=309;  $P<0.0001$ , dependent on type of operation with CPB; †chi-squared=28.5;  $P=0.0015$ , dependent on type of operation without CPB; ‡chi-squared=71.5;  $P<0.0001$ ; operations with CPB versus operations without CPB. CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting

Operation performed	Total		None		Drugs/fluids		Surgery OK		Change of surgical procedure		New Diagnosis		Other	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
With CPB														
CABG	916	48.4	386	42.1	182	19.9	170	18.6	92	10.0	64	7.0	21	2.3
CABG+vascular surgery	64	3.4	10	15.6	22	34.4	12	18.8	11	17.2	7	10.9	2	3.1
Other	170	9.0	38	22.4	45	26.5	41	24.1	16	9.4	26	15.3	3	1.8
Valve	523	27.7	51	9.8	72	13.8	277	53.0	55	10.5	31	5.9	37	7.1
Total CPB/% of all operations	1673	88.5	485	29.0	321	19.2	500	29.9	174	10.4	128	7.7	63	3.8*
Without CPB														
CABG	42	2.2	22	52.4	6	14.3	7	16.7	3	7.1	4	9.5	0	0.0
Other	53	2.8	25	47.2	7	13.2	8	15.1	2	3.8	4	7.5	6	11.3
Vascular surgery	123	6.5	63	51.2	39	31.7	4	3.3	3	2.4	11	8.9	3	2.4
Total non-CPB/% of all operations	218	11.5	110	50.5	52	23.9	19	8.7	8	3.7	19	8.7	9	4.1†
Total CPB and non-CPB/% of all operations	1891	100.0	595	31.5	373	20.4	519	28.7	182	9.6	147	5.2	72	3.8‡

*Types of operation and main consequences of TOE*

The types of operation for which TOE examinations were performed and the therapeutic consequences are presented in Table 2. The distribution of main consequences differed significantly between intervention with CPB and operations without CPB ( $P<0.0001$ ). In isolated on-pump coronary artery bypass grafting (CABG) procedures, quality control ('surgery OK') was rarely reported; these examinations had

the lowest percentage of consequences. The same was true for the off-pump CABG cases.

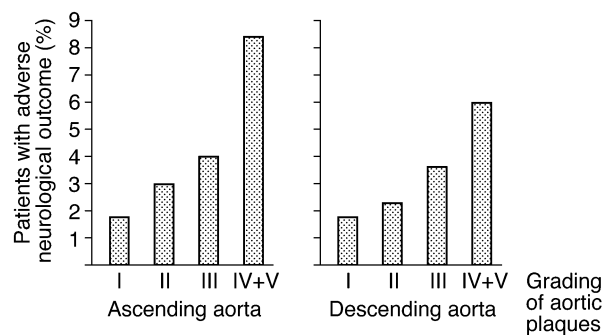
For the valve procedures and for the combined CABG procedures (CABG+vascular surgery), the incidence of therapeutic consequences was higher, and quality control ('surgery OK') was more important.

In the 123 vascular surgery procedures without CPB (mainly carotid endarterectomy and abdominal aortic surgery), more than 80% of all TOE examinations had only minor or no impact on patient management.

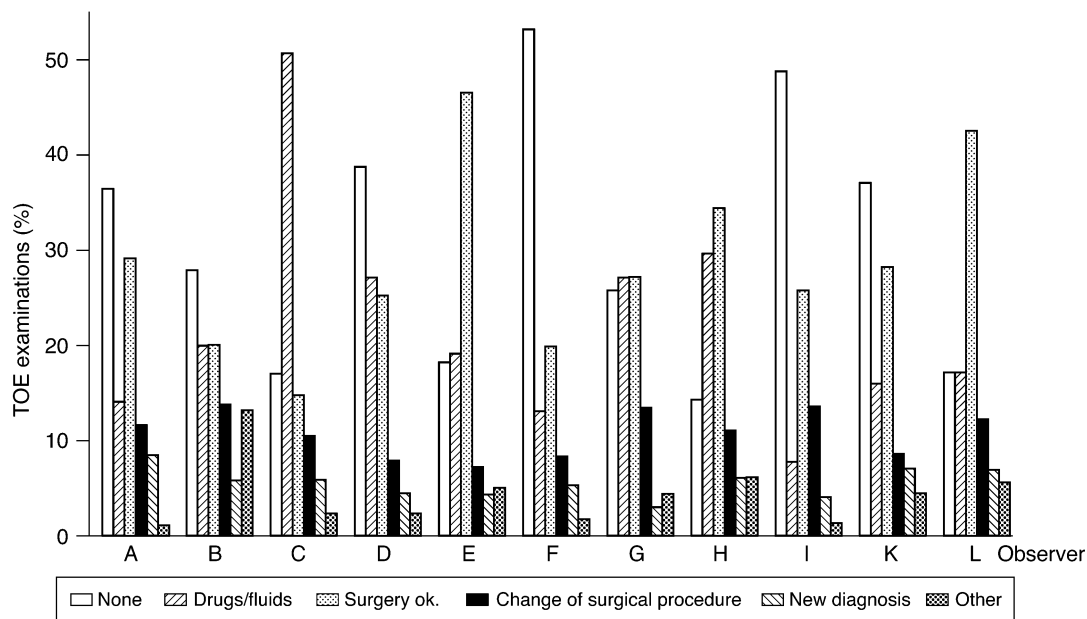
Tests for patent foramen ovale were performed in 1188 (63%) of all examinations. The diagnosis of a patent foramen ovale constituted 38% (54 cases) of the category 'new diagnosis' and was found in a total of 63 cases (5.3% of the 1188 examinations). In the remaining cases with a

**Table 3** Type of additional intervention based on TOE examination. CABG, coronary artery bypass grafts; IABP, intra-aortic balloon pump; PFO, patent forearm ovale; CPB, cardiopulmonary bypass; LA, left atrial

Additional intervention	n	Per cent of all interventions	Per cent of all examinations
Second pump run	9	4.9	0.48
Additional CABG	17	9.3	0.90
Additional CABG and IABP	22	12.1	1.16
IABP	60	33.0	3.17
MV replacement, not repair	6	3.3	0.32
No operation	2	1.1	0.11
No valve replacement	4	2.2	0.21
PFO closure	6	3.3	0.32
Reperfusion CPB	5	2.7	0.26
Composite graft	2	1.1	0.11
Repair of ascending aortic dissection	1	0.5	0.05
LA marsupialization	2	1.1	0.11
CABG with CPB	1	0.5	0.05
Replacement IABP (was in vena cava)	1	0.5	0.05
Resternotomy	7	3.8	0.37
Other	11	6.0	0.58
Not reported	26	14.3	1.4
Total number/total %	182	100.00	9.6



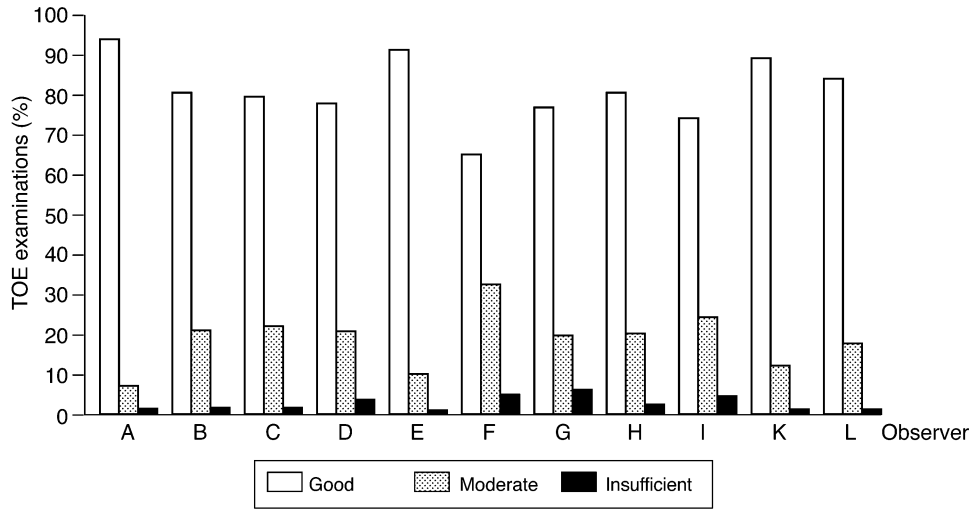
**Fig 1** Ascending and descending aortic plaques and neurologic outcome. Grading of aortic plaques: I=minimal, II=extensive intimal thickening, III=plaques <5 mm, IV=plaques >5 mm, V=mobile plaques (according to Montgomery<sup>17</sup>).



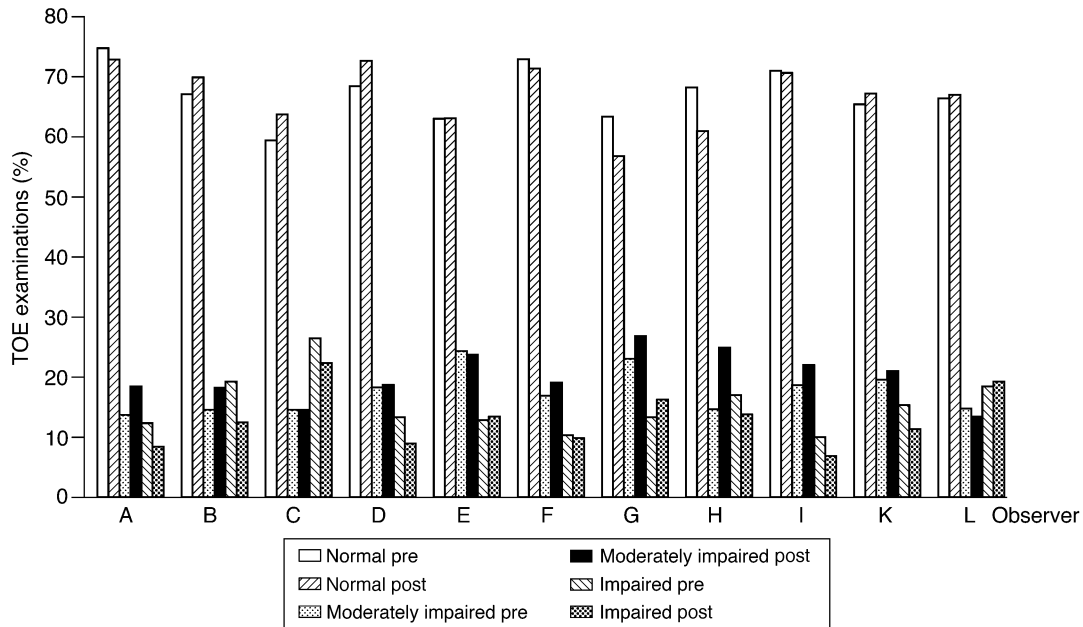
**Fig 2** Subjective ratings of therapeutic implications of TOE by 11 observers;  $n=1891$ . The ratings were observer dependent;  $\chi^2=305$ ;  $P<0.0001$ .

‘new diagnosis’, a new RWMA or a severe LV or right ventricular pump failure was present in 64 cases (43.5%). The remaining new diagnoses were a post-operative paravalvular leak after implantation of a prosthetic valve (three cases), a severe mitral insufficiency that was not corrected (three cases), an LV thrombus (two cases), and a variety of other diagnoses, such as LV outflow tract obstruction and severe aortic insufficiency in ascending aortic dissection (21 cases).

Additional interventions based on the TOE examinations are listed in Table 3. One-third of the 182 interventions consisted of intra-operative insertion of an IABP. Additional CABG was necessary in 39 (21.4%) cases. In two cases, the pre-operative TOE examination indicated that no operation was needed: an 80-yr-old woman undergoing mitral valve repair or replacement showed no mitral insufficiency in the TOE examination under anaesthesia, even after an increase in systemic



**Fig 3** Subjective ratings of TOE image quality by 11 observers;  $n=1723$  (168 missing values). Total ratings were ‘good’, 1394 (80.9%); ‘moderate’, 299 (17.4%); and ‘insufficient’, 30 (1.7%). The ratings were observer dependent; chi-squared=89;  $P<0.0001$ .



**Fig 4** Estimation of fractional area change (FAC) by 11 observers. The first set of two bars represents FAC estimated pre- and post-operatively and rated as normal. The second set of two bars represents FAC estimated pre- and post-operatively and rated as moderately impaired. The third set of two bars represents FAC estimated pre- and post-operatively and rated as impaired. Pre-operative FAC and the difference between pre- and post-operative FAC ( $\Delta$ FAC) were observer dependent. Pre-operative FAC: chi-squared=34;  $P=0.026$ ;  $\Delta$ FAC chi-squared=58;  $P=0.033$ . Total pre-operative ratings ( $n=1745$  (146 missing values)) were ‘normal’, 1183 (67.8%); ‘moderately impaired’, 316 (18.1%); and ‘impaired’, 246 (14.1%). Total post-operative ratings ( $n=1764$  (127 missing values)) were ‘normal’, 1203 (68.2%); ‘moderately impaired’, 358 (20.3%); and ‘impaired’, 203 (11.5%).

**Table 4** Requests for supervision by an anaesthetist or a cardiologist. <sup>†</sup>The column headed 'requests for either or both' does not simply represent the total number of requests. If both an anaesthesiologist and a cardiologist were called, the request was counted as only one. \*Chi-squared=452,  $P<0.0001$  between observers; <sup>†</sup>chi-squared=237,  $P<0.0001$  between experience level; \*\*chi-squared=427,  $P<0.0001$  between observers; <sup>‡</sup>chi-squared=218,  $P<0.0001$  between experience level

Observer	Previous Experience (no. of TOEs)	Requests for anaesthetist <i>n</i>	Requests for cardiologist <i>n</i>	Requests for either or both <sup>†</sup> <i>n</i>	% of all examinations performed
A	>300	3	9	12	6.3
B	>300	2	17	19	19.8
C	>300	0	7	7	14
D	>300	4	29	33	9.7
E	>300	10	20	27	9.4
F	150–300	7	7	13	7.4
G	150–300	0	13	13	23.6
H	150–300	10	3	13	15.7
I	<100	63	5	65	62.5
K	<100	16	8	24	16.4
L	<100	12	5	15	25.4
		* †		** ‡	
Total number/total %		127	123	241	12.7

vascular resistance with norepinephrine administration. Therefore, after consultation with a cardiologist, she was considered for medical treatment instead. In a 68-yr-old woman undergoing removal of an intra-cardiac fibroelastoma, the tumour was not found in the pre-operative TOE examination, and she did not undergo an operation.

#### *Aortic plaques and neurological outcome*

The neurological outcome of 1357 cases was entered into our database beginning in January 1997. Forty-two patients (3.1%) suffered from focal or generalized neurological damage after surgery. Intra-operative extension of aortic plaques of the ascending and of the descending aorta (Fig. 1) was correlated significantly with adverse neurological outcome ( $P<0.05$ ). For the ascending aorta, the number of patients in each grade (see legend to Fig. 1 for definitions) was: I, 13/765 (1.7%); II, 11/371 (2.9%); III, 2/49 (3.9%); IV+V, 1/11 (8.3%) ( $P=0.049$ ). For the descending aorta, the number of patients in each grade was: I, 10/567 (1.7%); II, 8/353 (2.2%); III, 8/217 (3.6%); IV+V, 4/64 (5.9%) ( $P=0.031$ ).

#### *Cardiologist's advice*

A cardiologist's advice was requested in 123 (6.5%) of the 1891 reported TOE examinations. The diagnosis was confirmed in 105 cases (85.3%); in 18 cases (14.6%) a new diagnosis was established. The new diagnosis led to a change in operative procedure in five cases (4%) and had no therapeutic consequences in 13 cases (10.6%).

#### *Inter-observer variability*

There was no significant difference between observers for the types of operation for which TOE was performed.

Individual observer-dependent variables are shown in Table 1 and in Figures 2–4. For therapeutic consequences (Fig. 2), variability was very large for 'none', 'drugs/fluids', and 'surgery OK'. Variability for 'change of surgical procedure' and 'new diagnosis' was not statistically significant. The ratio of reported to performed examinations (Table 1), testing for patency of the foramen ovale (not shown), image quality (Fig. 3), and pre-operative LV FAC and the difference between pre- and post-operative FAC (Fig. 4) were all significantly observer dependent. Catecholamines were used in 11% of all patients (observer-dependent range from 0 to 26%). Catecholamine use was not associated with the difference between pre-operative and post-operative LV FAC.

Inter-observer variability in requests for supervision by an anaesthetist was highly significant and dependent on the experience level of the observer. Variability in requests for a cardiologist's advice was not significant (Table 4).

## **Discussion**

The most important findings of this analysis of 1891 intra-operative TOE examinations are the following:

(a) Intra-operative TOE examinations contributed to patient management in cardiac surgery, even in isolated CABG procedures. (The 10% incidence of 'change of surgical procedure' following CABG represented 92 patients who profited from the examination.) For major vascular surgery, the consequences of TOE on intra-operative decision-making consisted mainly of modification of drug and fluid application.

(b) The percentage of reported examinations, most of the subjective ratings (e.g. interpretation of the consequences of TOE in patient management), and qualitative and semi-

quantitative measurements (e.g. FAC) were clearly observer dependent.

(c) The more objective consequences, however, such as a new diagnosis or a change of surgical procedure, varied much less between observers, and variability was not statistically significant.

(d) The search for quality improvement was evidently not futile, because younger colleagues needed significantly more supervision than did those with greater experience.

(e) The neurological outcome of the patient population was significantly worse when the size of aortic plaques increased, a fact that might suggest that TOE examinations in this specific field are reproducible.

### *Major limitations of this study*

The ratio of reported to performed TOE examinations was effectively observer dependent, as was the quality of individual record keeping.<sup>13</sup> The 11 observers performed different numbers of TOE examinations and had different levels of experience. Thus, we would expect a significant observer-dependence because of individual differences in skill. On the other hand, there were also important differences in interpretation between equally experienced observers.

In such an observational study it is somewhat cumbersome to provide data for the effect of TOE on patient therapy. The impossibility of clearly defining criteria for record keeping for 11 anaesthetists can be illustrated by the detection of new post-operative RWMA. With such a finding, is the consequence a 'new diagnosis' (new RWMA) or the fact that additional drugs were applied? Therefore, we decided to leave to the observer's discretion the consequence that seemed to be the most important. When TOE led to such an important consequence as the change of surgical procedure, for example, additional CABG because of detection of a severe new RWMA, then the consequence of this particular TOE was clear.

Another cause of error may be over interpretation of the importance of the TOE examination. While 82 IABP insertions (4.3% of reported examinations) were reported to be a direct consequence of the TOE examination, a total of 140 IABPs (7.6%) were inserted during operations in which a TOE examination was performed. Therefore, almost half of the IABP insertions were not reported to be a direct consequence of the TOE examination.

An often-cited limitation of intra-operative TOE is the fact that it is impossible for the anaesthetist to perform anaesthesia and echocardiography at the same time.<sup>19</sup> Because of the status of our institution as a university teaching hospital, our staff members supervise the senior residents performing anaesthesia in almost all cases, so they are usually not restricted in this way.

We did not present outcome data beyond the immediate post-operative period (with the exception of neurological outcome), and it may be argued that this early post-

operative outcome may not be decisive for final outcome after surgery. For complications of TOE, the same is true: we looked only at overt intra-operative complications. More subtle problems, such as late swallowing problems or sore throat,<sup>20</sup> were not taken into account. The aim of this study, however, was to evaluate the influence of TOE on intra-operative decision-making. The fact that the most important consequence (change of surgical procedure) was detected in as many as 184 patients (the two patients without operation included) makes the usefulness of intra-operative TOE evident.

The diagnosis of patent foramen ovale was made upon studying the atria during a microbubble injection only. Schneider and colleagues,<sup>21</sup> reported a small series of patients at autopsy and detected one missed diagnosis made with microbubbles alone; this corresponds to a sensitivity of 89%. Screening with colour Doppler echocardiography was not routine in our study, so our reported incidence of patent foramen ovale (5.3%) is low. It is also low when compared with other autopsy results, in which a 15–25% incidence of patent foramen ovale was found.<sup>22,23</sup>

The interpretation of information that is known to be difficult to obtain (e.g. high quality images of the ascending aorta<sup>24,25</sup>) will scatter as a function of the number of observations and the number of observers. Nevertheless, a correlation between aortic pathology and neurological outcome was found to be present.

According to our data, one may speculate that the usefulness of TOE in individual situations may also be observer dependent. The fact that TOE interpretation was more uniform for change of surgical procedure and new diagnoses, however, shows that a certain level of agreement was reached, sometimes with the help of either a supervising senior colleague or a cardiologist.

### *Comparison with results from other studies*

Comparison of our results with those of other studies is not easy because of the non-uniformity of the impact classification and the fact that our anaesthetists had to define the single most important impact on intra-operative decision-making. It was, therefore, not possible for them to choose multiple factors, even if more than one important diagnosis resulted from the TOE examination.

A large series published by Mishra and colleagues<sup>6</sup> also came to the conclusion that peri-operative management is influenced by TOE in valve surgery and in CABG surgery. Interestingly, they found that TOE helped or modified surgical decisions in as many as 27% of the CABG patients and in 11.6% of the valve surgery patients. The surgeons in that study revised the coronary grafts in 0.8% of the cases, compared with 2.1% in our population.

Mishra and colleagues reported changes of surgical procedure in CABG patients as 'minor changes in planned surgery' without specifying what those minor changes were. They reported 4.9% 'major changes in planned surgery',



which were also not specified, but this number is a lot closer to our finding of 10% surgical consequences in CABG patients. The high incidence of unsuspected findings in Mishra's study (11.6% of the valve procedures, 4.9% leading to major changes in planned surgery) is probably because of the fact that their patients were not given routine pre-operative transthoracic echocardiography (TTE) examinations. In our study, all valve surgery patients and a very large number of CABG patients had pre-operative TTE examinations by a cardiologist to rule out additional structural abnormalities that would have been overlooked by angiography.

The results from the study of Bergquist and colleagues<sup>7</sup> who evaluated 584 interventions in 75 CABG patients, are comparable with ours. The most important contributions of TOE were an indication for fluid administration (30%), anti-ischaemic therapy (21%), and critical surgical interventions (3%).

Whether modification of intra-operative fluid management should be considered a major or minor consequence for patient therapy may be debatable. However, the fact that fluid management, with the help of TOE, is very effective and rapid has been shown by Greim and colleagues.<sup>26</sup>

There were significant differences between cardiac surgery and major vascular surgery in the impact of TOE in our study. Non-cardiac surgery had a lower number of major consequences. Suriani and colleagues<sup>11</sup> reported an 81% incidence of TOE impact on intra-operative decision-making in non-cardiac surgery, but TOE was performed in a selected, high-risk patient population on demand of the attending anaesthetist. In our study, TOE was performed routinely in all major vascular surgery cases and still resulted in an overall TOE impact of 50%.

Series of different sizes involving complications of TOE<sup>27-29</sup> and several case reports of severe complications<sup>18 30 31</sup> have been reported. The incidence of severe pharyngeal lesions in awake patients seems to be well below 1% (Vignon,<sup>29</sup> 0.13%; Daniel,<sup>27</sup> 0.02%; Chan,<sup>28</sup> none). The data for complication rates of intra-operative TOE examinations in anaesthetized patients, however, are sparse. The incidence in our series was 0.1%. Fortunately, the two patients survived the complications. Since the study was completed, no serious complications have occurred at our institution, and our overall reported percentage of serious complications is approaching 0.05%.

This study was conducted with the help of standardized reports that all anaesthetists performing intra-operative TOE were supposed to complete. The percentage of reported examinations reached 82.4% and differed widely between observers. This is in accordance with results from a quality assurance programme reported by Rafferty<sup>13</sup> 6 yr ago. The overall reporting frequency in that study was 88%, and inter-observer variability was clearly demonstrated as well. Unlike Rafferty, we did not evaluate the quality and completeness of video recording, but frequent reviewing of tapes at our institution showed that we must improve

imaging and storing on tape. Inter-observer variability of some variables has been reported: record keeping and image quality,<sup>13</sup> FAC,<sup>15</sup> intra-operative decision-making,<sup>7</sup> theoretical background, and image interpretation.<sup>14</sup> It is probably not possible, however, to eliminate observer variability by more intensive training, as it is very difficult to convince experienced anaesthetists to use uniform anaesthetic techniques and/or decision algorithms for any given clinical situation. It seems possible, however, that different observers come to reproducible and nearly identical conclusions regarding LV function.<sup>32</sup>

Evaluation of atheromatous plaques in the thoracic aorta is not without difficulties: Konstadt and colleagues<sup>18</sup> showed that TOE is sensitive in the ascending aorta in 100% of cases, is specific for atheromatous disease in 60%, and has a positive predictive value of only 34% but a negative predictive value of 100%. Hartman and colleagues<sup>33</sup> showed a high reproducibility among three observers but only 57% interpretable images of the ascending aorta. We have shown that, even though it is difficult to obtain sufficient image quality in the ascending aorta, adverse neurological outcome is higher, in accordance with the increasing severity of TOE-detected atheromatosis of the ascending and descending aortas.

In conclusion, despite great inter-observer variability in certain variables related to the TOE examination, observer dependence for operative consequences was not significantly different. TOE had a considerable impact on patient management in this study, including cases of isolated coronary artery revascularization. A probable benefit for 182 patients was the fact that the surgical procedure was changed, and for two patients the planned operation was not performed; the money saved in these two cases alone would pay for almost one-third the cost of a complete echocardiography machine.

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