Evaluation of Transesophageal Echocardiography as a Diagnostic and Therapeutic Aid in a Critical Care Setting*

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Objectives: To assess the impact of transesophageal echocardiography (TEE) on therapeutic management in relation to pulmonary artery catheterization (PAC) in the ICU.

Design: Retrospective analysis of 108 consecutive TEE video and related patient files during a 7-month period.

Setting: A 33-bed medical and surgical ICU.

Methods: All critically ill patients with or without PAC in whom a TEE was performed, excluding postoperative cardiac surgical patients. Patients were divided in a cardiac and a septic group depending on the primary disease on admission to the ICU. The impact of TEE in relation to PAC on ICU management was evaluated in whether therapy changes were performed strictly on the basis of the TEE findings.

Main results: Of 64% of patients with a PAC, 44% underwent therapy changes after TEE: 41% in the cardiac and 54% in the septic subgroup. In 41% of patients without a PAC, TEE led to a change in therapy.

Conclusions: TEE results in altered therapeutic management in at least one third of our (noncardiac surgery) ICU patient population independent of the presence of a PAC.

(Chest 1995; 107:774-79)

Key words: cardiac failure; echocardiography; ICU management; pulmonary artery catheter; sepsis

Transesophageal color Doppler echocardiography (TEE) has now become a valid, noninvasive imaging tool for real-time bedside monitoring.1-3 The integrated approach of TEE, which demonstrates high-quality images of different cardiac structures and evaluates intracardiac blood flow, is advantageous in many critical situations.4

After the introduction of the flow-directed pulmonary artery catheter (PAC) by Swan et al,5 important advances were made in the field of hemodynamic monitoring. Since the application of TEE in critical care medicine, the importance of TEE has gradually increased over the years, even in noncardiac critically ill patients. The value and the impact of TEE in direct time relationship with PAC have not yet been fully elucidated.

The aim of this study was to evaluate the impact of TEE on patient management in noncardiac surgery critical care patients with and without a PAC and to look for the additional information obtained with TEE in those with a PAC.

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Manuscript received July 21, 1994; revision accepted October 11.

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Materials and Methods

Patient Selection

All critically ill patients in a 33-bed ICU who underwent a TEE during a 7-month period between January and July 1991 were included. Excluded were patients after cardiac surgery. The patient population was assorted into patients who did and who did not have a PAC at the time of the TEE. Moreover, in the two groups, three subgroups were made depending on the primary disease on admission to the ICU. When cardiac disease was the foremost indication of admittance, patients were assorted within a cardiac group. Patients with a systemic inflammatory response syndrome, as described by Bone et al,6 were allocated to a septic group. Finally, a third group of patients with both septic and cardiac disease or unclear diagnosis was defined.

TEE Analysis

In general, TEE was performed either as a primary (specific indication) or an additional diagnostic tool (insufficient data by PAC or transthoracic echocardiography [TTE]). To evaluate interobserver variability, 12 randomly selected observations were reviewed by two echocardiographers. In this study, the magnitude of the interobserver variability was in the range of 8 to 10%.

In our hospital, we apply the policy to perform a complete TTE before PAC and to record the whole TEE investigation on video. All efforts were made to obtain transthoracic images with the highest possible standard.

Before analysis of the video material by two independent investigators, some definitions were stated. Low filling status was defined as the combination of normal to hyperkinetic left ventricular function with small to nonexistent left ventricular
Table 1—Demographic Data of ICU Patients With/Without PAC*

<table>
<thead>
<tr>
<th>PAC</th>
<th>Present (n=66)</th>
<th>Absent (n=37)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE before TEE</td>
<td>63</td>
<td>37</td>
<td>NS</td>
</tr>
<tr>
<td>Ventilated</td>
<td>34</td>
<td>22</td>
<td>NS</td>
</tr>
<tr>
<td>Cardiac subgroup (n=63)</td>
<td>39</td>
<td>24</td>
<td>NS</td>
</tr>
<tr>
<td>IHD</td>
<td>19</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Cardiomyopathy</td>
<td>7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Valvular failure</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Septic subgroup (n=37)</td>
<td>24</td>
<td>13</td>
<td>NS</td>
</tr>
<tr>
<td>Sepsis</td>
<td>12</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Endocarditis</td>
<td>7</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Extracardiac subgroup (n=3)</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*IHD=Ischemic heart disease. Statistical analysis comparing the number of ICU patients with/without PAC in the different defined subgroups was performed by χ² test.*

end-systolic volume, low early left transmitral filling ratio, and biventricular pulmonary vein flow. Right ventricular dilatation was defined if the ratio of left and right ventricular lateromedial diameters exceeded 0.6. Right ventricular dysfunction was considered when right ventricular dilatation was present in conjunction with hypokinesis of the right ventricular free wall.

Medical File Analysis

A systematic review of every patient record was performed by two independent investigators, including the hemodynamic profile if a PAC was present. Four major indication areas to perform a TEE were defined. The first was evaluation of biventricular filling (evaluation of both end-diastolic and end-systolic areas). A second was focused on global and regional contractility. A third was evaluation of valve morphology and function. Finally, a fourth was evaluation of extracardiac structures.

The information retrieved with TEE beyond the knowledge from the PAC, if present, was considered useful whenever it involved initiation or adaptation of therapy or exclusion of major cardiovascular abnormality, e.g., ventricular septal defect, dissecting aortic aneurysm, endocarditis.

Device

All studies were performed on a Vingmed CFM 700 (Vingmed Sound AS, Horten, Norway) with a 5-MHz mechanical probe.7

Statistical Analysis

Distribution of the study parameters between the patient groups was assessed using the χ² test and nonparametric statistics. Statistical significance was considered if p<0.05.

RESULTS

Patient Characteristics and Subgroup Identification

Of 982 patients admitted to the ICU during the study period, 108 patients underwent a TEE (Table 1). The mean age was 62 years (range, 8 to 83 years; 32 women, 76 men). Sixty patients (56%) were ventilated at the time of the TEE.

The cardiac subgroup consisted of 63 patients and the septic group consisted of 37 patients. In a third subgroup (n=3) the primary indication was assessment of extracardiac abnormalities. Five patients with mixed abnormalities could not be asserted in either the septic or cardiac group and were excluded.

Safety and Feasibility

The TEE probe was inserted without difficulties in all patients. No serious complications arose during the TEE examination. In one medical file, transient monofocal ventricular extrasystoles were mentioned during insertion of the probe but no interruption prior to completion was needed. A relative contraindication existed in 11 (10%) of 108 patients: esophagitis in 4, esophageal varices in 3, oozing from the mouth or upper gastrointestinal tract in 4; nevertheless, these cases were investigated without problems and no complications were noted in the follow-up.

TEE Indications

Determinations of global and regional contractility was the main indication in 52 (50%) of the 103 patients. In 28 patients (27%), TEE was performed to assess the filling status. Valvular evaluation was the most important indication in 11 (11%) patients. In nine (9%) patients with sepsis, endocarditis had to be excluded. In three (3%) patients, TEE was done for evaluation of extracardiac structures.

TEE as a Diagnostic Adjunct

In 75 of 103 (74%) patients, TEE offered information to be considered useful in patient management. TEE resulted in exclusion of suspected abnormalities in 28 (27%) of 103 patients.

In the cardiac subgroup of 63 patients, 14 patients were in cardiogenic shock. Three hemodynamically unstable patients with acute myocardial infarction had a loud systolic murmur over the chest. TEE confirmed a ventricular septal defect in one and mitral regurgitation grade 4/4 in the two other patients due to chordal rupture. TEE gave limited information in the two patients with chordal rupture of the mitral valve in relation to the degree of the mitral valve insufficiency, but only TEE confirmed chordal rupture. The patient with the infarction-related ventricular septal defect could not be examined through TEE due to echo resistance. Unexpected thrombi or intracardiac vegetations were visualized in 2 of 63 (3%) patients as a supplementary echocardiographic finding. In 9 of the 63 (14%) patients, right ventricular dysfunction with dilatation, signs of increased right ventricular outflow impedance, or
both were shown. Furthermore, regional wall motion abnormalities were noted in 31 patients of this group (49%).

With respect to the patients with sepsis (n=37), TEE revealed an impaired left ventricular systolic function in 11 patients (30%) and predominant right ventricular dysfunction in 14 of 37 (38%) patients without earlier diagnosed cardiac disease. In two patients with sepsis, endocarditis was diagnosed due to valvular vegetations with valve insufficiency.

In two patients of the extracardiac group, a dissecting aneurysm of the thoracic aorta had to be excluded and in one patient special interest was focused on a parahilar pulmonary structure, which was visualized on chest radiograph. TEE showed fluid-filled cysts.

**Impact of TEE on Therapy Change in Patients With a PAC**

In 66 of 103 patients (64%), TEE was performed during PAC monitoring (Table 2). In 29 of 66 patients (44%), therapy changes were made. In eight patients with a PAC, TEE findings diagnosed hypovolemia, although an earlier performed filling challenge in six of eight patients (Table 3) was inconclusive during PAC monitoring. Subsequent filling demonstrated further augmentation of cardiac index in three of eight patients. Due to TEE, dobutamine was added to the therapy scheme or the dosage augmented in ten patients (Table 4), with subsequent good response in two and moderate response in three of ten patients. Urgent cardiac surgery or insertion of an intra-aortic balloon catheter was initiated due to the TEE findings in a total of 11 patients (Table 5). In the cardiac subgroup with a PAC (n=39), there were a total of 16 (41%) therapy changes. Prompt cardiac surgery for mitral valve replacement or ventricular septal defect was mediated by TEE in three patients.

In the subgroup with sepsis with a PAC (n=24), a total of 13 (54%) therapy changes were performed. In five patients, dobutamine therapy was started, and in six the intravenous fluid regimen was adjusted.

**Table 3—Summary of Cases in Which TEE Was Helpful in Decision Making With Respect to Volume Loading***

<table>
<thead>
<tr>
<th>Case No./Age, yr/Sex</th>
<th>ICU Admission</th>
<th>Before Filling</th>
<th>After Filling</th>
<th>Findings of TTE†</th>
<th>Findings of TTE†</th>
<th>Hemodynamic Data After TEE and Filling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/67/M</td>
<td>Sepsis</td>
<td>PAOP 7 CI 3.0</td>
<td>PAOP 15 CI 4.0</td>
<td>(1) RWMA small RV</td>
<td>Hyperdynamic RWMA</td>
<td>PAOP 15 CI 4.8</td>
</tr>
<tr>
<td>2/61/M</td>
<td>Sepsis</td>
<td>PAOP 8 CI 4.3</td>
<td>PAOP 14 CI 4.5</td>
<td>(2) Hyperdynamic RV</td>
<td>hypocontractility</td>
<td>PAOP 12 CI 4.7</td>
</tr>
<tr>
<td>3/71/M</td>
<td>Sepsis</td>
<td>PAOP 12 CI 1.5</td>
<td>PAOP 11 CI 2.5</td>
<td>Hyperdynamic RWMA, small RV</td>
<td></td>
<td>PAOP 13 CI 2.8</td>
</tr>
<tr>
<td>4/62/M</td>
<td>IHD</td>
<td>PAOP 15 CI 2.4</td>
<td>—</td>
<td>(1) Global dysfunction RV</td>
<td>hypokinetic but small</td>
<td>PAOP 15 CI 3.0</td>
</tr>
<tr>
<td>5/69/M</td>
<td>IHD</td>
<td>PAOP 14 CI 2.7</td>
<td>—</td>
<td>(2) Global dysfunction RV</td>
<td></td>
<td>PAOP 15 CI 2.8</td>
</tr>
<tr>
<td>6/78/F</td>
<td>Sepsis</td>
<td>PAOP 6 CI 2.2</td>
<td>PAOP 6 CI 2.5</td>
<td>Calibrated AV gradient 45 mm Hg global dysfunction</td>
<td>RWMA small RV</td>
<td>PAOP 9 CI 3.4</td>
</tr>
<tr>
<td>7/64/M</td>
<td>Sepsis</td>
<td>PAOP 13 CI 2.6</td>
<td>PAOP 14 CI 3.0</td>
<td>(1) Global dysfunction cardiac AV RV small dilatation</td>
<td></td>
<td>PAOP 16 CI 3.2</td>
</tr>
<tr>
<td>8/72/F</td>
<td>Sepsis</td>
<td>PAOP 8 CI 2.3</td>
<td>PAOP 7 CI 2.1</td>
<td>Hyperdynamic RV (1)</td>
<td>Hyperdynamic RWMA small RV</td>
<td>PAOP 12 CI 2.6</td>
</tr>
</tbody>
</table>

*AV=aortic valve; CI=cardiac index (L/min·m²); IHD=ischemic heart disease; LV=left ventricle; PAOP=pulmonary artery occlusion pressure (mm Hg); RV=right ventricle; RWMA=regional wall motion abnormalities; (1)=bad visualization; (2)=not conclusive.
†When not specified, comments consider the left ventricle; minus sign indicates no filling challenge.
**Therapy Adjustment Due to TEE in Patients Without a PAC**

In this group (n=37), therapy was modified in 15 patients, or 41% (Table 2). In the cardiac subset of patients (n=24), therapy was changed in 9 patients (38%). In the subgroup with sepsis, TEE resulted in 6 of 13 (46%) therapy changes.

**DISCUSSION**

The clinical application of TEE has been studied in many conditions and gradually this technique has been validated in the critical care setting. Some studies claim the importance of TEE in the postoperative follow-up after cardiac surgery. In the noncardiac surgery ICU, several authors have shown the additional value of TEE in decision making. We particularly studied the potential role of TEE in the ICU in patients instrumented with a PAC concerning therapy adjustment and decision making. Patients without PAC were not excluded to compare the value of TEE in both groups. In patients with life-threatening problems, the rapid and noninvasive evaluation of the suspected underlying event was the primary indication to perform TEE as an adjunct to PAC. We did not assess the value of TTE in the ICU setting; only when TTE appeared to supply insufficient or inadequate data was TEE performed. A negative bias toward a transthoracic approach was not present at the time of the examination, nor were echocardiographers aware of the study because of the retrospective nature of the study.

The results of our study confirm earlier findings by Oh et al in which TEE permitted the undoubtful exclusion of certain abnormalities because of its superior image quality, underlining the diagnostic role of TEE in the ICU. Our results demonstrate the comparable impact of TEE on ICU management in patients with (44%) and without (41%) a PAC. Despite the presence of a PAC, in some patients, initiation or adjustment of inotrope therapy or colloid filling was found to be necessary as well as other modifications in the therapy scheme, guided by the TEE examination.

Potential bias could be due to the retrospective nature of reviewing records and echographic files, although this was minimalized by excluding the mixed group of patients (4.6%). A second limitation of this study is that volumes of fluid or selection and dosing of inotropic drugs are uncontrolled variables. A control group was not included because of the retrospective nature. In addition, it is not easy to define a control population with respect to ethical reasons. These factors are inherently related to each clinical nonrandomized study.

Interobserver and reader variability of contractility and Doppler parameters have been extensively studied in a variety of studies, showing coefficients of

| Table 4—Summary of Cases With a PAC in Which TEE Findings Resulted in Start or Modification of Dobutamine Dosage* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Case No./Age, yr/Sex | Admission Diagnosis | Hemodynamic Data | DB | TEE | Hemodynamic Data |
| | | CVP | PAOP | CI | DB | CVP | PAOP | CI |
| 1/72/F | IHD | 8 | 14 | 2.3 | 5 | Global hypokinesia | 10 | 10 | 17 | 2.6 |
| 2/51/M | Sepsis | 13 | 15 | 4.2 | — | RWMA RV dilation | 7 | 7 | 14 | 7.1 |
| 3/81/M | Sepsis | 12 | 16 | 3.9 | — | Diastolic dysfunction | 5 | 12 | 15 | 4.6 |
| 4/63/M | IHD | 18 | 18 | 2.2 | — | Global dysfunction; RV dilation | 5 | 17 | 19 | 2.5 |
| 5/60/M | Sepsis | 11 | 17 | 4.7 | 3 | RWMA RV dilation | 10 | 14 | 15 | 6.4 |
| 6/59/M | IHD | 19 | 16 | 2.2 | 5 | RWMA RV dilation | 10 | 18 | 14 | 2.8 |
| 7/64/M | Sepsis | 18 | 15 | 3.2 | — | Small areas RV dilation | 8 | 17 | 14 | 3.4 |
| 8/78/F | Sepsis | 12 | 8 | 2.2 | — | Global dysfunction | 5 | 10 | 8 | 2.7 |
| 9/54/M | IHD | 15 | 17 | 2.5 | 5 | Global dysfunction; RV dilation | 10 | 15 | 13 | 2.7 |
| 10/68/F | IHD | 12 | 16 | 2.6 | 3 | Global dysfunction | 7 | 12 | 14 | 3.0 |

*Areas, both end-systolic and end-diastolic areas of the left ventricle; CI=cardiac index (L/min·m²); CVP=central venous pressure (mm Hg); DB=dobutamine (μg/kg·min); IHD=ischemic heart disease; LV=left ventricle; PAOP=pulmonary artery occlusion pressure (mm Hg); RV=right ventricle; RWMA=regional wall motion abnormalities; minus sign=no dobutamine present.

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variation of 4 to 11%. In this study, the magnitude of the interobserver variability was in line with these literature data.

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Important information can be obtained from right and left ventricular filling pressures by using the PAC, which leads to altered therapy schemes in about 50%. A drawback of hemodynamic monitoring with a PAC is the fact that precise evaluation of filling status in the mechanically ventilated patients remains difficult, particularly when tachycardia, high positive end-expiratory pressure ventilation, and decreased lung and cardiac compliance are present. TEE showed a low filling state in eight patients with cardiac conditions and sepsis (Table 3). Despite this small group of patients, TEE monitoring can be helpful in optimizing the filling status, although normal benefit was observed only in two of eight patients. Another feature in this study population with a PAC were patients in whom TEE clarified or confirmed a low-output state or a hemodynamic situation below expected metabolic needs (Table 4). In four of ten patients, a clearly demonstrable effect was obtained on cardiac index and left-sided filling pressure after adjusting inotropic support. In two of ten patients (one good and one moderate response), the initial dose was adjusted to the TEE findings. This does not necessarily mean that these interventions were the direct result of the TEE but the protocol of this investigation in one of five patients led to a modulation of the therapy scheme concerning either colloid filling or adding inodilatory therapy. Furthermore, the noninvasive nature of this technique should stimulate ICU clinicians to a supplementary TEE investigation.

Increased right atrial pressure was explained by TEE in three patients who had sustained trauma: we demonstrated significant tricuspid regurgitation, which is indeed known to be a late complication after blunt chest trauma.

In patients with sepsis, right ventricular dysfunction has been demonstrated to remain an important issue. When right ventricular outflow impedance is increased due to positive pressure ventilation or when pulmonary artery hypertension is present, right ventricular performance plays a determining role in the conservation of oxygen transport. Therefore, it is important to demonstrate early right ventricular failure, which often remains undetected by usual pressure monitoring. Applying a rapid computerized thermodilution method, some authors demonstrated a significant right ventricular systolic dysfunction (ejection fraction <39%), in conjunction with a 38% increase of right ventricular end-diastolic volume. In our study population of 103 patients, 26% revealed right ventricular dilatation, most often evident in patients with a septic hyperdymic or left ventricular low cardiac output syndrome.
With this retrospective analysis, we tried to demonstrate a supplementary value of TEE in a noncardiac surgical ICU setting. In conjunction with determination of cardiac performance and filling status, TEE offers a superior insight in cardiac morphology and valvular function. TEE results in altered therapeutic management in at least one third of our (noncardiac surgery) ICU patient population independent of the presence of a PAC.

It can be speculated that patients without supplementary TEE investigation will be "undertreated," as it could be the case with critically ill patients without, eg, PAC. However, the aspect of continuous monitoring remains the strongest power of the PAC. These data strengthen the need for smaller and less expensive ultrasound units. Careful combination of invasive pressure monitoring with TEE-determined intracardiac flows and volume estimation probably offers the most complete evaluation on line at the bedside on morphology and intracardiac hemodynamics. Prospective studies in selected conditions are needed to evaluate the role of TEE in critically ill patients concerning length of stay in the hospital, morbidity, and outcome.

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