Intraoperative 3D TOE - tool or toy?

Department of Anaesthesiology and Intensive Care Medicine II

Jörg Ender
Conflict of Interest

• Lecture fees:
  – Philips
  – GSK
Objectives

• Indications for perioperative echocardiography in general
• Status quo in german cardiac anesthesia departments
• Where 3 D TOE is helpfull
1 a device or implement, especially one held in the hand, used to carry out a particular function:
   - *gardening tools*
   - a thing used to help perform a job: *computers are an essential tool, the ability to write clearly is a tool of the trade*
   - a person used or exploited by another: *the beautiful Estella is Miss Havisham's tool*
   - *Computing* a piece of software that carries out a particular function, typically creating or modifying another program.
Recommendations for transoesophageal echocardiography: update 2010

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Document Reviewers: J.R.T.C. Roelandt3 and L. Piérardb

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Received 29 March 2010; accepted after revision 2 April 2010

Transoesophageal echocardiography (TOE) is a standard and indispensable technique in clinical practice. The present recommendations represent an update and extension of the recommendations published in 2001 by the Working Group on Echocardiography of the European Society of Cardiology. New developments covered include technical advances such as 3D transoesophageal echo as well as developing applications such as transoesophageal echo in aortic valve repair and in valvular interventions, as well as a full section on perioperative TOE.

Keywords Transoesophageal echocardiography • Interventional cardiology • 3D echocardiography
Recommendations Intraoperative TOE

- TOE **should** be used in adult patients undergoing cardiac surgery or surgery to the thoracic aorta under general anaesthesia, in particular, in valve repair procedures.
- TOE **may** be used in patients undergoing specific types of major surgery.....
Perioperative TOE

- Confirm or further define the preoperative diagnosis
- Exclude any new deterioration or unsuspected pathology
- Facilitate the intra-operative management of the patient
- Aid in surgical planning
- Evaluate the results of surgery
- Provide information for the postoperative care of the patient
Practice Guidelines for Perioperative Transesophageal Echocardiography

An Updated Report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography

*Developed by the American Society of Anesthesiologists Task Force on Perioperative Transesophageal Echocardiography: Daniel M. Thys, M.D., Chair, New York, New York; Martin D. Abel, M.B.B.Ch., Rochester, Minnesota; Robert F. Brooker, M.D., Wausau, Wisconsin; Michael K. Cahalan, M.D., Salt Lake City, Utah; Richard T. Connis, Ph.D., Woodinville, Washington; Peggy G. Duke, M.D., Atlanta, Georgia; David G. Nickinovich, Ph.D., Bellevue, Washington; Scott T. Reeves, M.D., Charleston, South Carolina; Marc A. Rozenz, Ph.D., M.D., Houston, Texas; Isobel A. Russell, M.D., San Francisco, California; Scott C. Streckenbach, M.D., Boston, Massachusetts; Pamela Sears-Rogan, M.D., Washington, D.C. (American Society of Echocardiography); and William J. Stewart, M.D., Cleveland, Ohio (American College of Cardiology).
For adult patients without contraindications, TEE should be used in all open heart (e.g. valvular procedures) and thoracic aortic surgical procedures and should be considered in CABG surgery.
Perioperative TOE /Purpose

- Confirm and refine the preoperative diagnosis
- Detect new or unsuspected pathology
- Adjust the anesthetic and surgical plan accordingly
- Assess the results of surgical intervention

SCA recommendations 2010
# Impact of perioperative TOE

<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Change surgical plan (%)</th>
<th>Patient Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click et al 2000</td>
<td>3245</td>
<td>15</td>
<td>Mixed Cardiac</td>
</tr>
<tr>
<td>Denault et al 2005</td>
<td>878</td>
<td>9.5</td>
<td>Aortic Valve operations</td>
</tr>
<tr>
<td>Mishra et al 1998</td>
<td>3660</td>
<td>27</td>
<td>Valve operation</td>
</tr>
<tr>
<td>Eltzschig et al 2009</td>
<td>12.566</td>
<td>9</td>
<td>Mixed cardiac</td>
</tr>
<tr>
<td>Silva et al 2010</td>
<td>850</td>
<td>23</td>
<td>Mixed Cardiac (Valves 70%)</td>
</tr>
<tr>
<td>Pre-CPB ( (n = 88) )</td>
<td>No. of new findings (surgical impact)</td>
<td></td>
<td></td>
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<tr>
<td>--------------------------</td>
<td>--------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of MR: mitral surgery canceled</td>
<td>15 (15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of MR: patient not operated</td>
<td>4 (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MR due to SAM: mitral surgery canceled</td>
<td>3 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASD/PFO</td>
<td>17 (16)</td>
<td></td>
<td></td>
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<tr>
<td>LA/LAA thrombus</td>
<td>11 (11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>9 (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of stenosis / aortic regurgitation</td>
<td>9 (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of tricuspid regurgitation</td>
<td>5 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stenosis / aortic regurgitation</td>
<td>3 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor LV function</td>
<td>3 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tricuspid regurgitation</td>
<td>3 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perforation of mitral valve leaflet</td>
<td>2 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of risk factors for SAM</td>
<td>2 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascending aorta aneurysm</td>
<td>1 (1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Every perioperative transoesophageal echo (TEE) study should generate a written report. A verbal report may be given at the time of the study. Important findings must be included in the written report. Where the perioperative TEE findings are new, or have led to a change in operative surgery, postoperative care or in prognosis, it is essential that this information should be reported in writing and available as soon as possible after surgery. The ultrasound technology and methodology used to assess valve pathology, ventricular performance and any other derived information should be included to support any conclusions. This is particularly important in the case of new or unexpected findings. Particular attention should be attached to the echo findings following the completion of surgery. Every written report should include a written conclusion, which should be comprehensible to physicians who are not experts in echocardiography.
Perioperative TOE report

- Cardiac chambers
- Valves
- Great vessels

Jack S. Shanewise, MD*, Albert T. Cheung, MD†, Solomon Aronson, MD‡, William J. Stewart, MD§, Richard L. Weiss, MD¶, Jonathan B. Mark, MD,* Robert M. Savage, MD‖, Pamela Sears-Rogan, MD**, Joseph P. Mathew, MD‡+, Miguel A. Quiñones, MD‡†, Michael K. Cahalan, MD‡‡, and Joseph S. Savino, MD†

*Division of Cardiac Anesthesia and Critical Care, Emory University School of Medicine, Atlanta, Georgia; †Department of Anesthesiology, University of Pennsylvania, Philadelphia, Pennsylvania; ‡Department of Anesthesia and Critical Care, University of Chicago, Chicago, Illinois; Departments of §Cardiology and ¶Cardiothoracic Anesthesiology, The Cleveland Clinic Foundation, Cleveland, Ohio; ‡Department of Cardiology, University of Pennsylvania Health System, Presbyterian Medical Center, Philadelphia, Pennsylvania; #Department of Anesthesiology, Duke University Medical Center, Veterans Affairs Medical Center, Durham, North Carolina; **Department of Cardiology, Washington Hospital Center, Washington, DC; ‡†Department of Anesthesiology, Duke University Medical Center, Durham, North Carolina; ‡‡Section of Cardiology, Baylor College of Medicine, Houston, Texas; and §§Department of Anesthesia, University of California–San Francisco, San Francisco, California
Figure 3. 20 cross-sectional views composing the recommended comprehensive TEE examination. Approximate multipane angle is indicated by the icon adjacent to each view. ME = mid esophageal, LAX = long axis, TG = transgastric, SAX = short axis, AV = aortic valve, RV = right ventricle, asc = ascending, desc = descending, UE = upper esophageal.
Aus dem Wiss. Arbeitskreis Kardioanästhesie

Einsatz der transösophagealen Echokardiographie in deutschsprachigen kardioanästhesiologischen Abteilungen*

- Ergebnisse einer Umfrage -

Application of transesophageal echocardiography in German speaking cardiac anaesthesia departments - Results of a survey

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¹ Abteilung für Anästhesie und Intensivmedizin II, Herzzentrum Leipzig, Universität Leipzig (Abteilungsleiter: Dr. J. Ender)
² Klinik für Anästhesiologie mit Schwerpunkt operative Intensivmedizin, Charité - Universitätsmedizin Berlin, Campus Virchow Klinikum und Campus Charité Mitte (Direktorin: Prof. Dr. Claudia Spies)
³ Abteilung Kardioanästhesiologie, Universitätsklinikum Ulm (Komm. Abteilungsleiter: Prof. Dr. U. Schirmer)
⁴ Klinik und Poliklinik für Anästhesiologie und Intensivtherapie, Universitätsklinikum Leipzig (Direktor: Prof. Dr. U.X. Kaisers)
Intraoperative TOE Examination

N=42

- 34% problem focused
- 29% pre standard post problem focused
- 29% all standard views pre and post
- 8% no fixed schedule

Ender et al  A&I 2009
Limiting factors / TOE examination

- Time: 7%
- Image quality: 23%
- Equipment: 23%
- Experience: 47%

N = 44

Ender et al A&I 2009
Time for TOE examination

- 64% < 5min
- 17% 5-10min
- 19% >10min

N = 42

Ender et al A&I 2009
How can 3 D TOE help?
RT 3D TOE Full Volume
Recommendations standard views

a. ME four chamber  b. ME two chamber  c. ME LAX  d. TG mid SAX

e. TG two chamber  f. TG basal SAX  g. ME mitral commissural  h. ME AV SAX

i. ME AV LAX  j. TG LAX  k. deep TG LAX  l. ME bicaval

m. ME RV inflow-outflow  n. TG RV inflow  o. ME asc aortic SAX  p. ME asc aortic LAX

q. desc aortic SAX  r. desc aortic LAX  s. UE aortic arch LAX  t. UE aortic arch SAX

Figure 3. 2D cross-sectional views composing the recommended comprehensive TEE examination. Approximate multipane angle is indicated by the icon adjacent to each view. ME = mid esophageal, LAX = long axis, TG = transgastric, SAX = short axis, AV = aortic valve, RV = right ventricle, asc = ascending, desc = descending, UE = upper esophageal.
Recommended Measurements not possible:
- STJ
- Ascending aorta
Measurements RV parameters

Eibel et al EACTA 2011
Improving quality of 2D views

ME 4 Ch and ME 2 Ch of the same heart beat, correcting for foreshortening
Improving quality of 2D views

TG midpap SAX and TG 2 Ch of the same heart beat!
Indications for 3D TOE

- Mitral valve disease
- Aortic valve disease
  - Measurements of diameter
- Prosthetic valve disease
  - Localization and extension of paraprosthetic leaks
- Guidance of percutaneous interventional procedures
“The recent advent of 3 D imaging has considerably enhanced TOE by providing relatively high image quality and several unique views, and by its capability to show intuitively understandable 3 D images to physicians not specialized in imaging.”
Assessment of Mitral Valve
Review

Real-Time Three-Dimensional Transesophageal Echocardiography Assessment of the Mitral Valve: Perioperative Advantages and Game-Changing Findings

Sherif E. Moustafa¹, Krishnaswamy Chandrasekaran¹, Bijoy Khandheria², Jamil Tajik², Farouk Mookadam¹

¹Department of Cardiovascular Diseases, Mayo Clinic, Scottsdale, AZ, ²Department of Cardiology, Aurora Medical Group, University of Wisconsin, Milwaukee, Wisconsin, USA

Real-time three-dimensional transesophageal echocardiography (RT-3D-TEE) represents a unique perioperative cardiovascular imaging tool which, without any need for off-line reconstruction, has been shown to be highly valuable for evaluating mitral valve and other intracardiac structures. It is highly probable that, in the near future, RT-3D-TEE will have a positive effect on the perioperative assessment of complex 3D mitral valve structures, as it provides important approaches to the pathophysiology of various mitral valve diseases, including prosthetic valves, and will become incorporated into everyday perioperative practice. The clinical applications and therapeutic implications of perioperative RT-3D-TEE in the thorough assessment of the mitral valve are briefly summarized in this review.

The Journal of Heart Valve Disease 2011;20:114-122
Table I: Patient characteristics of recently reported studies on the clinical applications and therapeutic implications of perioperative RT-3D-TEE in mitral valve assessment.

<table>
<thead>
<tr>
<th>Author/year</th>
<th>No. of patients</th>
<th>Mean age (years)</th>
<th>Gender ratio (M:F)</th>
<th>MV pathology</th>
<th>Surgical agreement with RT-3D-TEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grewal et al., 2009 (11)</td>
<td>42</td>
<td>63 ± 15</td>
<td>31:11</td>
<td>Myxomatous degeneration (88%); functional/ischemic MR (12%); cleft MV (2%).</td>
<td>98%</td>
</tr>
<tr>
<td>Wei et al., 2010 (13)</td>
<td>73</td>
<td>59</td>
<td>44:29</td>
<td>Rheumatic MV disease (52%); myxomatous degeneration (45%); Barlow’s disease (3%).</td>
<td>88%</td>
</tr>
<tr>
<td>Singh et al., 2009 (14)</td>
<td>11</td>
<td>64.77</td>
<td>5:6</td>
<td>Prosthetic mitral paravalvular regurgitation</td>
<td>100%</td>
</tr>
<tr>
<td>Kronzon et al., 2009 (15)</td>
<td>18</td>
<td>60 ± 14</td>
<td>10:8</td>
<td>Mitral ring dehiscence post MV repair or replacement (100%)</td>
<td>100% (in 10 patients)</td>
</tr>
<tr>
<td>Manda et al., 2008 (16)</td>
<td>18</td>
<td>55.3</td>
<td>14:4</td>
<td>MVP and associated chordae rupture with flail MV (100%)</td>
<td>89%</td>
</tr>
<tr>
<td>Ma et al., 2008 (17)</td>
<td>24</td>
<td>47 ± 11.6</td>
<td>13:11</td>
<td>Rheumatic MV disease (42%); MVP (42%); subacute bacterial endocarditis (12%); periprosthetic MV leakage (4%)</td>
<td>MVP/rupture chordate (95.8%); remaining pathology (100%)</td>
</tr>
<tr>
<td>Sugeng et al., 2008 (3)</td>
<td>47</td>
<td>60 ± 14</td>
<td>31:16</td>
<td>Myxomatous degeneration (89%); functional MR/dilated MV annulus (4%); rheumatic MV disease (4%); subacute bacterial endocarditis (2%)</td>
<td>96%</td>
</tr>
</tbody>
</table>

MR: Mitral regurgitation; MV: Mitral valve; MVP: Mitral valve prolapse.
Real-time three-dimensional echocardiographic assessment of mitral valve: Is it really superior to 2D transesophageal echocardiography?

Chirojit Mukherjee, Heinz Tschernich, Udo X Kaisers¹, Sarah Elbe², Joerg Seeburger¹, Joerg Ender

Department of Anaesthesiology and Intensive Care Medicine II, Heart Center Leipzig, University of Leipzig, *Department of Anaesthesia and Intensive Care Medicine, Medical Faculty, University of Leipzig, †Research Student, Department of Anaesthesiology and Intensive Care Medicine II, Heart Center, Leipzig, University of Leipzig, ‡Department of Cardiac Surgery, University of Leipzig, Germany

ABSTRACT

Aim of our study was to investigate the feasibility of use and possible additional value of real-time 3D transesophageal echocardiography (RT-3D-TEE) compared to conventional 2D-TEE in patients undergoing elective mitral valve repair. After ethical committee approval, patients were included in this prospective study. After induction of anesthesia, a comprehensive 2D-TEE examination was performed, followed with RT-3D-TEE. The intraoperative surgical finding was used as the gold standard for segmental analysis. Only such segments which were surgically corrected either by resection or insertion of artificial chords were judged pathologic. A total of 50 patients were included in this study; usable data were available from 42 of these patients. Based on the Carpenter classification, the pathology found was type I in 2 (5%) patients, type II in 9 (9/20%) patients, and type III in 4 (4/20%) patients. We found that 3D imaging of complex mitral disease involving multiple segments, when compared to 2D-TEE did not show any statistically significant difference. RT-3D-TEE did not show any major advantage when compared to conventional 2D-TEE for assessing mitral valve pathology, although further study in a larger population is required to establish the validity of this study.

Key words: Real time 3D TEE, minimally invasive mitral valve repair, 2D TEE

Table 5: Comparison between 3D online and 2D online analyses

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (T+/D+) %</th>
<th>Sensitivity (T+/D+) %</th>
<th>Specificity (T-/D-) %</th>
<th>Specificity (T-/D-) %</th>
<th>Accuracy Online %</th>
<th>Accuracy offline %</th>
<th>McNemar test P= .05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2D online</td>
<td>3D online</td>
<td>2D online</td>
<td>3D online</td>
<td>2D online</td>
<td>3D online</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>88</td>
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<td>94</td>
<td>100</td>
<td>93</td>
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<td>1.0</td>
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<tr>
<td>A2</td>
<td>89</td>
<td>95</td>
<td>83</td>
<td>88</td>
<td>86</td>
<td>93</td>
<td>0.25</td>
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<tr>
<td>A3</td>
<td>67</td>
<td>100</td>
<td>97</td>
<td>100</td>
<td>88</td>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>P1</td>
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<td>0.5</td>
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<td>82</td>
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<td>91</td>
<td>96</td>
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<td>PC</td>
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<td>100</td>
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<td>98</td>
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</table>

# DTEE Online vs offline

## Table 4: Comparison between 2D online and 2D offline analyses

<table>
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<tr>
<th></th>
<th>Sensitivity (T+/D+) %</th>
<th>Sensitivity (T+/D+) %</th>
<th>Specificity (T-/D-) %</th>
<th>Specificity (T-/D-) %</th>
<th>Accuracy online %</th>
<th>Accuracy offline %</th>
<th>McNemar test P= .05</th>
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</tr>
<tr>
<td>A1</td>
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<td>94</td>
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<td>97</td>
<td>100</td>
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<td>100</td>
<td>98</td>
<td>98</td>
<td>X</td>
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</table>

Exact measurement of the aortic annulus
Exact localization of residual regurgitation after MV repair
Exact localization of paravalvular leakage MV 2D
Exact localization of paravalvular leakage MV 3D
Exact localization of paravalvular leakage AV

Aortic view

LVOT view
Guide for catheter-based intervention

TAVI
Placement of the prosthesis
Prediction of the annuloplasty ring size in patients undergoing mitral valve repair using real-time three-dimensional transoesophageal echocardiography

J. Ender¹*, S. Eibel¹†, C. Mukherjee¹, D. Mathioudakis¹, M.A. Borger², S. Jacobs³, F.W. Mohr², and V. Falk³

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Received 21 December 2010; accepted after revision 22 March 2011
TOE guided sizing / 2D

AML height

Intercommissural distance
TOE guided sizing / 3D
## Results

### Table 3: Differences between implanted ring and predicted annuloplasty ring size (n = 53, proportions in parentheses)

<table>
<thead>
<tr>
<th>Diff. in mm</th>
<th>3D pre-OP</th>
<th>3D post-OP</th>
<th>ID pre-OP dias</th>
<th>ID pre-OP sys</th>
<th>OD post-OP dias</th>
<th>OD post-OP sys</th>
<th>AML pre-OP</th>
<th>AP post-OP dias</th>
<th>AP post-OP sys</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>37 (70)</td>
<td>44 (83)</td>
<td>5 (9.4)</td>
<td>4 (7.5)</td>
<td>34 (64.2)</td>
<td>41 (77.4)</td>
<td>–</td>
<td>22 (41.5)</td>
<td>23 (43.4)</td>
</tr>
<tr>
<td>−2</td>
<td>8 (15)</td>
<td>7 (13.2)</td>
<td>11 (20.8)</td>
<td>11 (20.8)</td>
<td>12 (22.6)</td>
<td>9 (17)</td>
<td>–</td>
<td>5 (9.4)</td>
<td>14 (26.4)</td>
</tr>
<tr>
<td>+2</td>
<td>8 (15)</td>
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3D, measurements in 3D loop (visual estimation method); ID, measurements of intercommissural distance pre-operatively in 2D end-diastolic and end-systolic; OD, measurements of outer ring diameter postoperatively in 2D end-diastolic and end-systolic; AML, measurements of the maximum height of the anterior leaflet in 2D; AP, measurements of anterior–posterior leaflet distance in 2D end-diastolic and end-systolic.

\[
\begin{align*}
r &= 0.91 \\
r &= 0.55 \\
r &= 0.54 \\
r &= 0.75
\end{align*}
\]
RT 3D TEE:

- creates not only beautiful pictures for better orientation
- improves the quality of 2D imaging using X-plan mode
- allows to get a lot of information within a short period of time
- can be used to guide catheter-based interventions
- Allows image guided sizing
Intraoperative 3D TOE is a useful tool!!

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