

Intraoperative Transesophageal Echocardiography during Surgery for Congenital Heart Defects in Pediatrics

Submitted for the fulfillment of Doctorate Degree in Pediatrics

By

Baher Matta Nashed Hanna, M. Sc.

Assistant Lecturer of Pediatrics
Cairo University

Under the supervision of

M. Fawzan Shaltout, MD

Professor of Pediatrics and Pediatric Cardiology
Head of the Pediatric Cardiology Division
Cairo University

Sonia A. El-Saiedi, MD

Professor of Pediatrics and Pediatric Cardiology
Cairo University

Wael M. Lotfy, MD, MRCP

Professor of Pediatrics and Pediatric Cardiology
Cairo University

Mohamed A. Seliem, MD, FACC

Professor of Pediatrics, Department of Pediatrics
University of Pennsylvania School of Medicine
Division of Pediatric Cardiology, The Children's Hospital of Philadelphia, USA

Cairo University
2009

Abstract

OBJECTIVES: The importance of intraoperative transesophageal echocardiography in congenital heart surgery, its diagnostic accuracy and its predictive value on long-term follow-up. **STUDY DESIGN:** This is a retrospective study done on 1156 patients in which the preoperative and postoperative transthoracic echo reports were analyzed together with the intraoperative transesophageal echo reports performed for patients undergoing ventricular and atrial septal defect closure, mitral valve repairs and right ventricular outflow tract repairs. **RESULTS:** Intraoperative transesophageal echocardiography detected the highest incidence of residual pathology in mitral valve repairs and the least in atrial septal defect repairs. It was also helpful in defining patients in need for surgical revision intraoperatively. Intraoperative transesophageal echocardiography was most accurate in diagnosing residual mitral regurgitation and least accurate in atrial septal defects. On follow up, residual septal defects had a tendency to close spontaneously, residual right ventricular outflow tract gradients tended to decline, while the residual mitral valve regurgitations were liable to progress. **CONCLUSION:** Intraoperative transesophageal echocardiography has an influential role in congenital heart surgery; it may miss a significant percentage of residual defects but is able to predict the fate of residual lesions detected intraoperatively.

KEY WORDS: intraoperative transesophageal echocardiography, residual lesion, residual lesions, septal defects, mitral valve, right ventricular outflow tract.

Contents

Abstract	i
Contents	iii
Acknowledgements	v
List of tables	vi
List of figures	vii
List of abbreviations	x
1. Introduction and Aim of Work	1
1.1. Introduction	3
1.2. Aim of Work	5
2. Review of Literature	7
2.1. History of pediatric intraoperative epicardial echocardiography	9
2.2. History of pediatric intraoperative TEE	10
2.3. Utility of intraoperative transesophageal echocardiography	13
2.3.1. <i>Recognition of common lesions</i>	13
2.3.2. <i>Assessment of residual pathology</i>	21
2.3.3. <i>Assessment of pressure gradients</i>	21
2.3.4. <i>Assessment of ventricular filling and function</i>	22
2.4. Influences of intraoperative transesophageal echocardiography on anesthetic and surgical management	25
2.5. Outcome and effectiveness of pediatric intraoperative echocardiography	26
2.6. Indications for transesophageal echocardiography in the patient with congenital heart disease	27
2.6.1. <i>Intraoperative transesophageal echocardiography</i>	27
2.6.2. <i>TEE in the cardiac catheterization laboratory</i>	28
2.7. Safety issues	30
2.7.1. <i>Patient safety</i>	30
2.7.2. <i>Probe safety</i>	31
2.7.3. <i>Endocarditis prophylaxis during the procedure</i>	32

2.7.4. Contraindications to transesophageal echocardiography in the patient with congenital heart disease	32
2.8. Knowledge base, skills and training necessary to perform a transesophageal echocardiographic examination in the patient with congenital heart disease	34
2.8.1. Cognitive skills, technical skills, and training guidelines	34
2.8.2. Recommendations for physicians not formally trained in transesophageal echocardiography performance in patients with congenital heart disease	36
2.8.3. Maintenance of skills	38
2.9. Performance of transesophageal echocardiography in a pediatric patient	39
2.9.1. Instrumentation	40
2.9.2. Anatomical and spatial relationships	41
2.9.3. Order of examination	44
3. Material and Methods	67
3.1. Patients	69
3.2. Echocardiographic examinations	70
3.3. Statistical analysis	70
4. Results	71
4.1. Overview	73
4.2. Septal Defects	73
4.2.1. Ventricular septal defects	73
4.2.2. Atrial septal defects	79
4.3. Mitral valve repairs	87
4.4. Right ventricular outflow tract repairs	97
5. Discussion	107
6. Conclusion and Recommendations	117
Summary	121
References	125
Arabic summary	143

Acknowledgements



Words fall short of containing my genuine appreciation; but a lifetime of gratitude will prove it.

My supervisors and professors Dr. Fawzan Shaltout, Dr. Sonia El-Saiedi, and Dr. Wael Lotfy: thank you for offering me much of your time, effort and experience.

Dr. Seliem: your generous hospitality will always be remembered.

Professors Dr. Ramzi El-Baroudy and Dr. Emad Salem: unceasingly I continue to learn from you through your model.

My friends and fellow doctors: Andrew Irwin, Bassem Matta, Maged Fakhry and Osama Abdel-Aziz: This work would not have come to light without you.

My family: without you, I would not be where I am today, and most certainly would not have accomplished what I have.

“As we express our gratitude, we must never forget that the highest appreciation is not to utter words, but to live by them”

John F. Kennedy

And I, hereby, second that saying



List of tables

<i>Table 2.1: Pre-bypass echocardiographic data by type of congenital heart defect.....</i>	<i>13</i>
<i>Table 2.2: Post-bypass echocardiographic data by type of congenital heart defect repair or surgical procedure.....</i>	<i>23</i>
<i>Table 2.3: Contraindications for transesophageal echocardiography.....</i>	<i>33</i>
<i>Table 2.4: Guidelines for training and maintenance of competence.....</i>	<i>36</i>
<i>Table 4.1: Types of ventricular septal defects.</i>	<i>74</i>
<i>Table 4.2: Intraoperative TEE findings in VSD</i>	<i>75</i>
<i>Table 4.3: Predischarge TTE versus intraoperative TEE in VSD</i>	<i>77</i>
<i>Table 4.4: Follow up TTE versus intraoperative TEE in VSD</i>	<i>78</i>
<i>Table 4.5: Types of Atrial Septal Defects.</i>	<i>79</i>
<i>Table 4.6: Intraoperative TEE findings in ASD</i>	<i>81</i>
<i>Table 4.7: Predischarge TTE versus intraoperative TEE in ASD</i>	<i>82</i>
<i>Table 4.8: Follow up TTE versus intraoperative TEE in ASD</i>	<i>83</i>
<i>Table 4.9: The incidence of residual septal defects according to intraoperative TEE</i>	<i>85</i>
<i>Table 4.10: Predischarge TTE findings in septal defects</i>	<i>86</i>
<i>Table 4.11: Follow up TTE findings in septal defects</i>	<i>86</i>
<i>Table 4.12: Types of mitral valve repairs.....</i>	<i>87</i>
<i>Table 4.13: Intraoperative TEE findings in mitral valve repairs</i>	<i>89</i>
<i>Table 4.14: Predischarge TTE versus intraoperative TEE in mitral valve repairs</i>	<i>92</i>
<i>Table 4.15: Follow up TTE findings in mitral valve repairs and the correlation to intraoperative TEE findings</i>	<i>94</i>
<i>Table 4.16: Types of right ventricular outflow tract repairs.....</i>	<i>97</i>
<i>Table 4.17: Intraoperative TEE findings in RVOT repairs.....</i>	<i>99</i>
<i>Table 4.18: Predischarge TTE findings vs. intraoperative TEE in RVOT repairs</i>	<i>102</i>
<i>Table 4.19: Follow up TTE versus intraoperative TEE in RVOT repairs</i>	<i>104</i>

List of figures

Figure 2.1: Types of transesophageal echocardiographic probes.	12
Figure 2.2: (a-f) Echocardiographic images of septal defects.	17
Figure 2.3: (a-e) Echocardiographic images of complex lesions.....	20
Figure 2.4: Continuous wave Doppler interrogation of left ventricular outflow tract in patient with subaortic obstruction.	21
Figure 2.5: Instrumentation of transesophageal echocardiography.....	40
Figure 2.6: Transesophageal echocardiography probe and multiplanar transducer:position basics.....	40
Figure 2.7: TEE probe: anatomical relationships.....	41
Figure 2.8: Anatomic reference scheme and nomenclature	41
Figure 2.9: Anatomical relationships of transesophageal echocardiography.. ...	42
Figure 2.10: Spatial relationships of transesophageal echocardiography	42
Figure 2.11: Anatomic reference scheme and nomenclature	43
Figure 2.12: Midesophageal four-chamber (A).....	46
Figure 2.13: Midesophageal four-chamber (A).....	46
Figure 2.14: Midesophageal four-chamber (A).....	47
Figure 2.15: Midesophageal mitral commissural (G).....	47
Figure 2.16: Midesophageal mitral commissural (G).....	48
Figure 2.17: Midesophageal two-chamber (B).....	48
Figure 2.18: Midesophageal two-chamber (B).....	49
Figure 2.19: Midesophageal long axis (C).....	49
Figure 2.20: Midesophageal long axis (C).....	50
Figure 2.21: Midesophageal right ventricular inflow-outflow (M).	50
Figure 2.22: Midesophageal right ventricular inflow-outflow (M).	51
Figure 2.23: Midesophageal bicaval (L).....	51
Figure 2.24: Midesophageal bicaval (L).....	52
Figure 2.25: Midesophageal ascending aortic long axis view (P).....	52
Figure 2.26: Midesophageal ascending aortic long axis view (P).....	53
Figure 2.27: Midesophageal aortic valve long axis (I).	53
Figure 2.28: Midesophageal aortic valve long axis (I).	54
Figure 2.29: Midesophageal ascending aortic short axis view (O).	54
Figure 2.30: Midesophageal ascending aortic short axis view (O).	55
Figure 2.31: Midesophageal aortic valve short axis (H).....	55
Figure 2.32: Midesophageal aortic valve short axis (H).....	56
Figure 2.33: Upper esophageal aortic arch long axis (S).	56
Figure 2.34: Upper esophageal aortic arch long axis (S).	57
Figure 2.35: Upper esophageal aortic arch short axis (T).	57
Figure 2.36: Descending aortic long axis (R).....	58

Figure 2.37: Descending aortic long axis (R).....	58
Figure 2.38: Descending aortic short axis (Q).	59
Figure 2.39: Descending aortic short axis (Q).	59
Figure 2.40: Transgastric midshort axis (D).....	60
Figure 2.41: Transgastric midshort axis (D).....	60
Figure 2.42: Transgastric basal short axis (F).	61
Figure 2.43: Transgastric basal short axis (F).	61
Figure 2.44: Transgastric two-chamber (E).	62
Figure 2.45: Transgastric two-chamber (E).	62
Figure 2.46: Transgastric long axis (J).	63
Figure 2.47: Transgastric long axis (J).	63
Figure 2.48: Transgastric right ventricular inflow (N).	64
Figure 2.49: Transgastric right ventricular inflow (N).	64
Figure 2.50: Deep transgastric long axis (K).	65
Figure 2.51: Deep transgastric long axis (K).	65
Figure 4.1: Types of ventricular septal defects.	74
Figure 4.2 (a): Intraoperative TEE findings in VSD.....	76
Figure 4.2 (b): Intraoperative TEE findings in VSD.....	76
Figure 4.3: Predischage TTE versus intraoperative TEE in VSD.....	77
Figure 4.4: Follow up TTE versus intraoperative TEE in VSD.....	78
Figure 4.5: Types of atrial septal defects.....	79
Figure 4.6: Intraoperative TEE findings in ASD.....	81
Figure 4.7: Predischage TTE versus intraoperative TEE in ASD.....	82
Figure 4.8: Follow up TTE versus intraoperative TEE in ASD.....	83
Flow diagram 1: Illustrating the intraoperative TEE findings in septal defect repairs and relation to the postoperative predischage TTE	Error! Bookmark not defined.
Figure 4.9 (a): The incidence of residual septal defects according to intraoperative TEE.....	85
Figure 4.9 (b): Comparison between VSD vs. ASD: residual defects and cases requiring bypass.....	85
Figure 4.10: Predischage TTE findings in septal defects.....	86
Figure 4.11: Follow up TTE findings in septal defects.....	86
Figure 4.12: Types of mitral valve repairs.....	88
Figure 4.13 (a): Intraoperative TEE findings in mitral valve repairs.....	90
Figure 4.13 (b): Intraoperative TEE findings in mitral valve repairs.....	90
Figure 4.13 (c): Intraoperative TEE findings in mitral valve repairs: residual mitral regurgitation (MR) and cases requiring bypass, comparison between different degrees of severity.	91
Figure 4.14 (a): Predischage TTE findings in mitral valve repair.....	92
Figure 4.14 (b): Predischage TTE vs. intraoperative TEE in mitral valve repairs	93
Figure 4.15 (a): Follow up TTE findings in mitral valve repairs.....	94
Figure 4.15 (b): Follow up TTE vs. intraoperative TEE in mitral valve repairs....	95

<i>Flow diagram 2: Illustrating the intraoperative TEE findings in mitral valve repairs and relation to the postoperative predischARGE TTE</i>	Error!
Bookmark not defined.	
<i>Figure 4.16: Types of right ventricular outflow tract repairs.....</i>	97
<i>Figure 4.17(a): Intraoperative TEE findings in RVOT repairs.....</i>	99
<i>Figure 4.17(b): Intraoperative TEE findings in RVOT repairs.....</i>	100
<i>Figure 4.17(c): Intraoperative TEE findings in RVOT repairs: comparison between different degrees of severity.</i>	100
<i>Figure 4.18 (a): PredischARGE TTE findings in RVOT repairs.....</i>	103
<i>Figure 4.18 (b): PredischARGE TTE vs. intraoperative TEE in RVOT repairs....</i>	103
<i>Figure 4.19 (a): Follow up findings in RVOT repairs.....</i>	105
<i>Figure 4.19 (b): Follow up TTE versus intraoperative TEE in RVOT repairs....</i>	105
<i>Flow diagram 3: Illustrating the intraoperative TEE findings in right ventricular outflow tract repairs and relation to the postoperative predischARGE TTE.....</i>	Error! Bookmark not defined.

List of abbreviations

AMVL	Anterior mitral valve leaflet
AO	Aorta
APV	Absent pulmonary valve
ASD	Atrial septal defects
AVC	Atrio-ventricular canal
CHD	Congenital heart disease
FN	False negative
FP	False positive
IVC	Inferior vena cava
LA	Left atrium
lcc	Left coronary cusp
LPA	Left pulmonary artery
LV	Left ventricle
LVOT	Left ventricular outflow tract
ME	Mid esophageal
ncc	Non-coronary cusp
NPV	Negative predictive value
PA	Pulmonary artery
PMVL	Posterior mitral valve leaflet
PPV	Positive predictive value
RA	Right atrium
rcc	Right coronary cusp
RPA	Right pulmonary artery
RV	Right ventricle
RVOT	Right ventricular outflow tract
RVOTO	Right ventricular outflow tract obstruction
SVC	Superior vena cava
TEE	Transesophageal echocardiography
TN	True negative
TOF	Tetralogy of Fallot
TP	True positive
TTE	Transthoracic echocardiography
TV	Tricuspid valve
UE	Upper esophageal
VSD	Ventricular septal defects

Introduction and Aim of Work

1.1. Introduction

The transesophageal approach is recognized as an effective window for imaging intracardiac and vascular structures due to the proximity of the esophagus to the heart and major blood vessels. Initial consideration of using the esophagus as a site of echocardiographic imaging was made in the mid- 1970s by Frazin *et al.* who described the use of an esophageal M-mode ultrasonic crystal (Frazin *et al.*, 1976). The early 1980s marked the introduction of a gastroscope with a two-dimensional transducer. Since the introduction of transesophageal echocardiography (TEE) to the intraoperative setting in the late 1980s (Schluter *et al.*, 1982), multiple publications have documented the utility of this imaging modality in adult cardiac patients in the evaluation of valvular repair (Goldman *et al.*, 1987; Taams *et al.*, 1989; Foster *et al.*, 1998) and prosthetic valve function (Nellessen *et al.*, 1988; van den Brink *et al.*, 1989), and for monitoring of myocardial ischemia (Leung *et al.*, 1989; Smith *et al.*, 1985) and left ventricular preload (Abel *et al.*, 1987; De Bruijn 1987; Harpole *et al.*, 1989).

As surgical advances in the care of patients with heart disease rapidly evolve, the contributions of TEE continue to be demonstrated (Applebaum *et al.*, 1998; Shanewise *et al.*, 2002; Pu *et al.*, 2003). Immediate detection of suboptimal surgical interventions by TEE has been shown to improve surgical outcomes, thereby avoiding subsequent reoperations and reducing morbidity, mortality, and cost (Benson and Cahalan, 1995). Until the early 1990s, intraoperative evaluation of infants and children undergoing surgery for congenital heart was not feasible via the transesophageal approach due to the fact that probe sizes were not suitable for examination in young children. The subsequent development of miniaturized technology initially generated a number of studies which demonstrated that TEE can be performed safely in the pediatric age group and provides substantial benefit as well (Ritter, 1990; Ritter and Thys, 1989; Stumper *et al.*, 1990; Ritter *et al.*, 1989; Lam *et al.*, 1991). This experience has been substantiated over the last decade.' (Miller-Hance and Russell, 2005)