The Impact of Focused Transthoracic Echocardiography in Non-cardiac Anaesthesia and Surgery

by

David Jeffrey Canty

M.B.B.S (Hons) F.A.N.Z.C.A. PGDipEcho

Faculty of Medicine

Submitted in fulfilment of the requirements for the Degree of DOCTOR OF PHILOSOPHY

University of Tasmania November 2012
Dedication

To Susan, Byron and Zara,
without their understanding and support,
this journey would not have been made.
"A new idea is first condemned as ridiculous and then dismissed as trivial, until finally, it becomes what everybody knows"

Swami Vivekananda

19th century Indian saint, philosopher
Abstract

Transthoracic echocardiography (TTE), usually performed by cardiologists, is increasingly used by physicians at the patient’s bedside. Focused TTE is an abbreviated study used as part of clinical assessment to improve diagnostic accuracy and aid clinical decision-making in real-time. Cardiac disease is a leading cause of perioperative mortality, which may be contributed to by poor preoperative cardiac assessment. The hypothesis is that focused TTE influences cardiovascular diagnosis and management by anaesthetists.

An audit of focused TTE revealed changes to anaesthetist’s management plans in 53% of 87 patients undergoing emergency surgery (75%), elective surgery (56%) and preoperative assessment clinic assessment (22%). TTE helped guide preoperative cardiology referral, anaesthetic technique, invasive monitoring and postoperative disposition. TTE was possible in 10 out of 24 patients with intraoperative haemodynamic instability, avoiding need for transtoesophageal echocardiography and associated risk of oesophageal injury.

I conducted prospective observational studies of 100 patients attending the preoperative assessment clinic for elective surgery; and 99 patients requiring emergency surgery. In patients with clinically suspected cardiac disease or age ≥65 years, the anaesthetist’s management plan was compared before and after TTE performed by an independent anaesthetist.

In elective surgery, the TTE findings triaged patients to those with significant cardiac pathology leading to a step-up in care (20%), and those without, leading to a step-down in care (34%). Management was also altered in asymptomatic patients aged over 65 years (step-up in 10%, step-down in 15%). An overall reduction in hospital resource use (cardiology referral, invasive monitoring and intensive care) and improved efficiency (less delays and hospital visits) resulted.

In emergency surgery, TTE revealed significant cardiac pathology in 75%, altering preoperative assessment in 67% leading to a higher step-up (36%) than step-down (8%) in treatment. Haemodynamic treatment changes (such as fluids and invasive monitoring) were more common (30%) than changes to surgical workflow and postoperative intensive care (14%). In a retrospective cohort sub-analysis, the mortality of 64 hip fracture patients who received preoperative TTE was compared to a randomised retrospective control group with similar risk factors. Mortality was lower in the TTE group over the 30 days (4.7% v 15.2%, p=0.047) and 12 months after surgery (17.1% versus 33.3%, p=0.031). Hazard of death over 12 months was reduced after adjustment for known risk factors (hazard ratio 0.41, 95% CI 0.2 to 0.85, p=0.016).

In surgical patients at increased risk of cardiac disease, preoperative focused TTE by anaesthetists frequently changed management decisions and may reduce mortality.
Declaration

This is to certify that

This thesis comprises only original work completed by the author for the degree Doctor of Philosophy at the University of Tasmania.

1. This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

2. This thesis may be made available for loan and limited copying and communication in accordance with the Copyright Act 1968.

3. The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

4. The thesis is less than 100,000 words in length, exclusive of tables, figure legends, bibliographies and appendices.

Dr. David Canty (candidate)          Date
Statement of co-authorship

The following people and institutions contributed to the publication of work undertaken as part of this thesis:

Dr David Canty, School of Medicine, University of Tasmania

Professor Colin Royse, Department of Pharmacology, University of Melbourne

Professor David Kilpatrick, Department of Medicine, University of Tasmania

Professor Alistair Royse, Department of Surgery, University of Melbourne

Dr. Leigh Bowman, Department of Cardiology, The Royal Hobart Hospital

Dr. Andrea Bowyer, Department of Anaesthesia and Pain Management, The Royal Melbourne Hospital

A/Professor John Faris, Freemantle School of Medicine, University of Notre Dame

A/Professor Michael Veltnam, Department of Anaesthesia and Pain Management, Joondalup Hospital

Dr. Darsim Haji, Department of Emergency Medicine, Frankston Hospital

Paper 1
Located in chapter 2


Candidate was the primary author (75%) and with author 2 (25%) contributed to the idea, its formalisation and development.

Paper 2
Located in chapter 3


Candidate was the primary author (70%) and with author 2 (20%) and 5 (5%) contributed to the idea, its formalisation and development. Candidate performed all data collection which was reviewed by author 4 (5%). Author 3 (5%) contributed to the manuscript.

Paper 3
Located in chapter 4


Candidate was the primary author (70%) and with author 2 (15%) and 5 (10%) contributed to the idea, its formalisation and development. Candidate performed most of the data collection which was contributed to by author 2 and 5. Authors 3 and 4 (5%) contributed to the manuscript.
Paper 4    Located in chapter 5


Candidate was the primary author (70%) and with author 2 (15%) and 5 (5%) contributed to the idea, its formalisation and development. Candidate supervised the data collection by research nurses and author 4 (5%). Author 3 (5%) contributed to the manuscript.

Paper 5    Located in chapter 1 and 6


Author 1 (35%) and candidate (35%) equal primary authors who contributed to the idea, its formalisation and development. Authors 3 (10%), 4 (5%), 5 (5%) and 6 (5%) contributed to the manuscript.

We the undersigned agree with the above stated “proportion of work undertaken” for each of the above published (or submitted) peer-reviewed manuscripts contributing to this thesis:

Signed: ____________________  ____________________  ____________________

Prof Colin Royse  Prof David Kilpatrick  Prof James Vickers
Supervisor  Supervisor  Head of School
School of Medicine  School of Medicine  School of Medicine
University of Melbourne  University of Tasmania  University of Tasmania

Date:_____________________  ___________________  ___________________
Acknowledgements

Professor Colin Royse provided the vision, guidance and support for this research program and he continues to be a remarkable role-model and I am honoured to work with him and his team. Professor Alistair Royse provided considerable support from design to print, was the information technology expert and also performed echocardiography. Professor David Kilpatrick provided valuable insight from a cardiologist’s point of view and provided guidance and administrative support as a supervisor from The University of Tasmania. I also was inspired and encouraged by other original members of the Ultrasound Education Group including A/Prof John Faris and A/Prof Michael Veltnam. Dr Darsim Haji, a fellow candidate, provided valuable assistance, comradeship and good company.

I am grateful for the assistance of a number of staff at the Royal Melbourne and Royal Hobart hospitals, including the Directors of Anaesthesia; Dr Stephen Reid, Dr Haydn Perndt and A/Prof Daryl Williams, and the research nurses who performed screening and recruitment of subjects and data collection and entry: Mrs Zelda Williams, Ms Jenny Pang, Ms Susan Kelly, Mr Rodney Jansen, Ms Penelope Turner and Ms Teresa Grabek. I also thank the anaesthetists who assisted in performing echocardiographic studies: Dr. David Andrews, Dr. Paul Soeding and Dr. Andrew MacCormick. Statistical advice was given by Dr. Sandy Clarke from The University of Melbourne.

This PhD candidature was funded by a scholarship grant provided by Australasian and New Zealand College of Anaesthetists. Additional funding was provided by The University of Melbourne (Department of Pharmacology).

I am indebted to both my parents for setting me on track and providing inspiration and support.
TABLE OF CONTENTS

ABSTRACT ........................................................................................................ IV
DECLARATION .................................................................................................... V
STATEMENT OF CO-AUTHORSHIP ................................................................ VI
ACKNOWLEDGEMENTS .................................................................................. VIII
Table of Contents.......................................................................................... IX
Table of Figures............................................................................................. XI
List of Tables.................................................................................................. XII
Abbreviations................................................................................................ XIII
Preface ............................................................................................................. XIV

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW ......................................... 15
  1.1. INTRODUCTION ............................................................................................. 16
  1.2. ULTRASOUND FOR NON-CARDIOLOGISTS-WHERE DID IT START? .......... 17
  1.3. THE ROLE OF TECHNOLOGY IN THE EVOLUTION OF ULTRASOUND USE ....... 19
  1.4. THE EXPERTISE PYRAMID .......................................................................... 21
      1.4.1. ULTRASOUND IN INTENSIVE CARE .................................................... 24
      1.4.2. ULTRASOUND IN ANAESTHESIA ........................................................ 24
  1.5. IS ULTRASOUND EFFECTIVE? ...................................................................... 27
      1.5.1. TRANSESOophageal ECHOCARDIOGRAPHY ....................................... 27
      1.5.2. TRANSThoracic ECHOCARDIOGRAPHY .............................................. 33
      1.5.3. LUNG ULTRASOUND ........................................................................... 37
      1.5.4. ULTRASOUND-GUIDED VASCULAR ACCESS ....................................... 38
      1.5.5. ULTRASOUND-GUIDED REGIONAL ANAESTHESIA ............................... 38
      1.5.6. GOAL-FOCUSED TTE: ......................................................................... 39
      1.5.6.1. SePARATING THE “GOOD, THE BAD AND THE UGLY” ....................... 39
  1.6. AIMS AND OBJECTIVES OF THIS WORK ................................................. 43
      1.6.1. AUDIT OF ANAESTHETIST-PERFORMED ECHOCARDIOGRAPHY ........ 44
      1.6.2. PREOPERATIVE ASSESSMENT CLINIC ............................................... 45
      1.6.3. EMERGENCY SURGERY ....................................................................... 47
      1.6.4. OUTCOME AFTER HIP FRACTURE SURGERY ...................................... 48

CHAPTER 2
AUDIT OF ANAESTHETIST PERFORMED ECHOCARDIOGRAPHY .... 49
  2.1. INTRODUCTION ............................................................................................. 50
  2.2. METHODS ..................................................................................................... 51
  2.3. RESULTS ........................................................................................................ 52
      2.3.1. PREOPERATIVE ASSESSMENT CLINIC ............................................... 58
      2.3.2. TTE BEFORE ANAESTHESIA AND SURGERY ................................... 58
      2.3.3. UNDER ANAESTHESIA AND DURING SURGERY ................................. 59
      2.3.4. POSTOPERATIVE STUDIES ................................................................. 59
  2.4. DISCUSSION .................................................................................................. 60
Table of Figures

Figure 1.1 The “expertise pyramid”.

Figure 1.2 Examples of echocardiography of three patients.

Figure 2.1 Summary of indications and outcomes in an audit of anaesthetist performed echocardiography.

Figure 3.1 Summary of transthoracic echocardiography findings and changes to management plan in 100 patients studied in the preoperative assessment clinic.

Figure 4.1 Summary of findings of clinical assessment, preoperative transthoracic echocardiography and changes to diagnosis and management plans in 99 emergency surgery patients at risk of cardiac disease.

Figure 5.1 Flowchart illustrating how 130 patients who underwent hip fracture surgery were allocated into different groups.

Figure 5.2 Summary of the influence of preoperative transthoracic echocardiography on diagnosis and management in 64 hip fracture patients at risk of cardiac disease.

Figure 5.3 Kaplan Meier survival curve comparing mortality of 130 patients over 12 months after hip fracture surgery in transthoracic echocardiography.
List of Tables

Table 1.1  Society defined guidelines for training and achieving competence in echocardiography.
Table 1.2  Summary of goal-focused transthoracic echocardiography examination protocols.
Table 1.3  Summary of studies on the impact of transoesophageal echocardiography on decision-making in surgery and intensive care.
Table 1.4  Summary of studies on the impact of transthoracic echocardiography on decision-making in intensive care and emergency medicine.
Table 1.5  Basic Haemodynamic State Classification.
Table 2.1  Examples of positive transthoracic echocardiographic findings affecting management decisions.
Table 2.2  Examples of negative or reassuring transthoracic echocardiographic findings affecting management decisions.
Table 2.3  Haemodynamic state and new echocardiographic findings.
Table 2.4  Influence of echocardiography on management decisions.
Table 3.1  Focused transthoracic echocardiography indications, findings and effect on management in 100 patients in the preoperative assessment clinic.
Table 3.2  Positive transthoracic echocardiographic findings that led to a step-up in management in 20 patients out of a total of 100 examined in the preoperative assessment clinic.
Table 3.3  Negative or reassuring transthoracic echocardiographic findings that led to a step-down in management in 34 patients out of 100 examined in the preoperative assessment clinic.
Table 4.1  Positive transthoracic echocardiographic findings that led to a step-up in management in 36 out of 99 emergency surgery patients.
Table 4.2  Negative or reassuring transthoracic echocardiographic findings that led to a step-down in management in 8 out of 99 emergency surgery patients.
Table 5.1  Characteristics of the 130 hip fracture patients, according to study group.
Table 5.2  Transthoracic echocardiographic findings that influenced management decisions in 33 out of 64 hip fracture surgery patients.
Table 5.3  Predictors of death among hip fracture patients during the first 12 months after surgery.
Table 6.1  Summary of studies on the impact of transthoracic echocardiography on decision-making and outcome in non-cardiac anaesthesia.
Table 6.2  Examples of smartphone apps and educational websites for echocardiography.
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST</td>
<td>Focused Assessment with Sonography in Trauma.</td>
</tr>
<tr>
<td>FATE</td>
<td>Focused Assessed Transthoracic Echocardiography;</td>
</tr>
<tr>
<td>GA</td>
<td>General Anaesthesia;</td>
</tr>
<tr>
<td>HCU</td>
<td>Hand Carried Ultrasound</td>
</tr>
<tr>
<td>HDU</td>
<td>High dependency unit;</td>
</tr>
<tr>
<td>HEART scan</td>
<td>Haemodynamic Echocardiographic Assessment in Real Time;</td>
</tr>
<tr>
<td>ICU</td>
<td>Intensive Care Unit;</td>
</tr>
<tr>
<td>Intraop</td>
<td>During the surgical procedure</td>
</tr>
<tr>
<td>LV</td>
<td>Left Ventricle;</td>
</tr>
<tr>
<td>NBE</td>
<td>National Board of Echocardiography;</td>
</tr>
<tr>
<td>NOF</td>
<td>Neck Of Femur;</td>
</tr>
<tr>
<td>Postop</td>
<td>After the surgical procedure;</td>
</tr>
<tr>
<td>Preop</td>
<td>Before the surgical procedure;</td>
</tr>
<tr>
<td>PTEeXAM</td>
<td>Examination of special competence in advanced perioperative transoesophageal echocardiography;</td>
</tr>
<tr>
<td>RV</td>
<td>Right Ventricle;</td>
</tr>
<tr>
<td>TOE</td>
<td>Transoesophageal Echocardiography;</td>
</tr>
<tr>
<td>TTE</td>
<td>Transthoracic Echocardiography;</td>
</tr>
<tr>
<td>2D</td>
<td>Two-dimensional;</td>
</tr>
</tbody>
</table>
My first memorable experience with echocardiography was as in 2003 when Professor Colin Royse talked me through the basic 20 transoesophageal echocardiography (TOE) views during a cardiac surgery operation. In a subsequent patient, I discovered a previously undetected flail mitral leaflet, which prompted the surgeon to repair the valve. Never before had I encountered an intraoperative monitor have such a profound effect on the course of surgery. TOE was rapidly becoming standard of care in cardiac surgery and Professor Royse postulated this may occur in non-cardiac surgery. This encouraged me to further my echocardiography training via the specialty of cardiac anaesthesia.

I was disappointed that my initial consultant post did not include cardiac anaesthesia and I found it difficult to maintain my echocardiography skills, but serendipitously I was given finance to purchase a TOE machine for use in non-cardiac surgery. Technology had improved and I procured two laptop-sized machines with additional transthoracic echocardiography (TTE) probes. I was amazed at the high quality imaging of TTE which is possible in awake patients in a variety of settings. For the next few exciting weeks there were few patients that escaped my TTE probe!

When requested to perform preoperative TTE on an elderly fractured neck of femur patient, I was surprised to detect critical aortic stenosis with severe biventricular failure and pulmonary hypertension. This led to palliative treatment and may have avoided an intraoperative disaster. At that point I realised the potential for TTE in anaesthesia. Again I turned to Professor Royse who has shown me how to unlock and share this new knowledge in this research programme.

At the start of the doctorate I was only aware of a small number of anaesthetists performing TTE. By completion in 2012, over 20% of anaesthetists and intensivists in Australia and New Zealand have completed the University of Melbourne Certificate or Diploma in Ultrasound, which has changed focus from TOE to TTE and other surface-based ultrasound applications. The Australian and New Zealand College of Anaesthetist’s professional document on TOE credentialing is under revision to include goal-directed TTE. TTE training is spreading beyond anaesthesia to both postgraduate and undergraduate medicine, as the concept of ‘ultrasound-assisted examination’ has applications in fields of medicine beyond anaesthesia and Professor Royse’s initial predictions.
The following chapters have been removed for copyright or proprietary reasons

CHAPTER 2
AUDIT OF ANAESTHETIST PERFORMED ECHOCARDIOGRAPHY
Published as:
DOI: http://dx.doi.org/10.1093/bja/aep165

Abstract
Intra-operative trans-oesophageal echocardiography is increasingly used for guiding intra-operative management decisions during non-cardiac surgery. Trans-thoracic echocardiography (TTE) equipment and training is becoming more available to anaesthetists, and its point-of-care application may facilitate real-time haemo-dynamic management and preoperative screening.
Methods: We conducted an audit of trans-thoracic and trans-oesophageal echocardiograms, performed by an anaesthetist at a tertiary referral centre over a 9-month period, to identify the effect of echocardiography on clinical decision-making in patients undergoing non-cardiac surgery. The indications for echocardiography followed published guidelines.
Results: Echo-cardiographic examinations of 97 patients included 87 trans-thoracic, and 14 trans-oesophageal studies. Of 36 studies conducted in the preoperative clinic, eight revealed significant cardiac pathology, necessitating cardiology referral or admission before surgery. Preoperative trans-thoracic echocardiograms performed on the day of surgery (n=39) led to two cancellations of surgery owing to end-stage cardiac disease, the institution of two unplanned surgical procedures (drainage of pleural and pericardial effusions), and to significant changes in anaesthetic and haemodynamic management, or both in 18 patients. Greater influence on management occurred with emergency surgery (75%) than elective surgery (43%). Intra-operative trans-thoracic (n=10) and trans-oesophageal (n=14) echocardiography also altered management (altered surgery in two patients, cancellation in one, and altered haemo-dynamic management in 18 patients).
Conclusions: Anaesthetist-performed point-of-care TTE and thoracic ultrasound may have a high clinical impact on the peri-operative management of patients scheduled for non-cardiac surgery.

CHAPTER 3
FOCUSED TTE IN THE PREOPERATIVE ASSESSMENT CLINIC
Published as:
DOI: http://dx.doi.org/10.1111/j.1365-2044.2012.07118.x

ABSTRACT
This prospective observational study investigated the effect of focused transthoracic echocardiography in 99 patients who had suspected cardiac disease or were ≥ 65 years old, and were scheduled for emergency non-cardiac surgery. The treating anaesthetist completed a diagnosis and management plan before and after transthoracic echocardiography, which was performed by an independent operator. Clinical examination rated cardiac disease present in 75%; the remainder were asymptomatic. The cardiac diagnosis was changed in 67% and the management plan in 44% of patients after echocardiography. Cardiac disease was identified by echocardiography in 64% of patients, which led to a step-up of treatment in 36% (4% delay for cardiology referral, 2% altered surgery, 4% intensive care and 26% intra-operative haemodynamic management changes). Absence of cardiac disease in 36% resulted in a step-down of treatment in 8% (no referral 3%, intensive care 1% or haemodynamic treatment 4%). Pre-operative focused transthoracic echocardiography in patients admitted for emergency surgery and with known cardiac disease or suspected to be at risk of cardiac disease frequently alters diagnosis and management.
CHAPTER 4
FOCUSED TTE IN EMERGENCY SURGERY
Published as:
DOI: [http://dx.doi.org/10.1111/j.1365-2044.2012.07118.x](http://dx.doi.org/10.1111/j.1365-2044.2012.07118.x)

ABSTRACT
This prospective observational study investigated the effect of focused transthoracic echocardiography in 99 patients who had suspected cardiac disease or were ≥ 65 years old, and were scheduled for emergency non-cardiac surgery. The treating anaesthetist completed a diagnosis and management plan before and after transthoracic echocardiography, which was performed by an independent operator. Clinical examination rated cardiac disease present in 75%; the remainder were asymptomatic. The cardiac diagnosis was changed in 67% and the management plan in 44% of patients after echocardiography. Cardiac disease was identified by echocardiography in 64% of patients, which led to a step-up of treatment in 36% (4% delay for cardiology referral, 2% altered surgery, 4% intensive care and 26% intra-operative haemodynamic management changes). Absence of cardiac disease in 36% resulted in a step-down of treatment in 8% (no referral 3%, intensive care 1% or haemodynamic treatment 4%). Pre-operative focused transthoracic echocardiography in patients admitted for emergency surgery and with known cardiac disease or suspected to be at risk of cardiac disease frequently alters diagnosis and management.

CHAPTER 5
FOCUSED TTE AND OUTCOME AFTER HIP FRACTURE SURGERY Published as:
DOI: [http://dx.doi.org/10.1111/j.1365-2044.2012.07300.x](http://dx.doi.org/10.1111/j.1365-2044.2012.07300.x)

Abstract
Hip fracture surgery is associated with a high rate of mortality and morbidity; heart disease is the leading cause and is often unrecognised and inadequately treated. Pre-operative focused transthoracic echocardiography by anaesthetists frequently influences management, but mortality outcome studies have not been performed to date. Mortality over the 12 months after hip fracture surgery, in 64 patients at risk of cardiac disease who received pre-operative echocardiography, was compared with 66 randomised historical controls who did not receive echocardiography. Mortality was lower in the group that received echocardiography over the 30 days (4.7% vs 15.2%, log rank p=0.047) and 12 months after surgery (17.1% vs 33.3%, log rank p=0.031). Hazard of death was also reduced with pre-operative echocardiography over 12 months after adjustment for known risk factors (hazard ratio 0.41, 95% CI 0.2-0.85, p=0.016). Pre-operative echocardiography was not associated with a delay in surgery. These data support a randomised controlled trial to confirm these findings.

CHAPTER 1 & CHAPTER 6
INTRODUCTION AND LITERATURE REVIEW & SUMMARY
Published as
DOI: [http://dx.doi.org/10.1213/ANE.0b013e31826a79c1](http://dx.doi.org/10.1213/ANE.0b013e31826a79c1)
Abstract

The use of ultrasound in the acute care specialties of anesthesiology, intensive care, emergency medicine, and surgery has evolved from discrete, office-based echocardiographic examinations to the real-time or point-of-care clinical assessment and interventions. "Goal-focused" transthoracic echocardiography is a limited scope (as compared with comprehensive examination) echocardiographic examination, performed by the treating clinician in acute care medical practice, and is aimed at addressing specific clinical concerns. In the future, the practice of surface ultrasound will be integrated into the everyday clinical practice as ultrasound-assisted examination and ultrasound-guided procedures. This evolution should start at the medical student level and be reinforced throughout specialist training. The key to making ultrasound available to every physician is through education programs designed to facilitate uptake, rather than to prevent access to this technology and education by specialist craft groups. There is evidence that diagnosis is improved with ultrasound examination, yet data showing change in management and improvement in patient outcome are few and an important area for future research.
### APPENDIX

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>HEART scan protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix 2</td>
<td>HEART scan report form</td>
</tr>
<tr>
<td>Appendix 3</td>
<td>Research questionnaires Preoperative assessment clinic study</td>
</tr>
<tr>
<td>Appendix 4</td>
<td>Research questionnaires Emergency surgery study</td>
</tr>
<tr>
<td>Appendix 5</td>
<td>Research presentations, grants and awards</td>
</tr>
</tbody>
</table>
APPENDIX 1  HEARTscan Protocol

Summarised from Faris\textsuperscript{31} and Royse.\textsuperscript{26,104,120}

Up to 3 windows used until adequate information obtained of:

1. Haemodynamic state
   Based on the left ventricular volume, systolic function and atrial pressure estimation (Table 1.3).

2. Valve and pericardium
   Haemodynamic significant lesions – that could cause haemodynamic compromise during or after anaesthesia and surgery. For valves this equates to moderate or severe severity as defined in guidelines from The American Society of Echocardiography.\textsuperscript{168,169}
   Specific HEART scan positive criteria include:

Aortic stenosis
   Leaflet separation $< 1.5$ cm in the Left parasternal long axis view OR
   Heavy calcification and unable to see valve opening

Aortic regurgitation
   Wall hugging jet
   Jet extends into the ventricle $> 25$ mm
   Jet:LVOT height $> 25\%$

Mitral stenosis
   Reduced leaflet opening
   “Hockey stick” appearance of either leaflet
   PISA on the atrial side of the valve

Mitral regurgitation
   Flail leaflet or ruptured papillary muscle
   Regurgitant jet area $> 20\%$ of left atrial area
   Wall hugging jet

Tricuspid regurgitation
   Wall hugging jet
   Central jet area $> 5\text{cm}^2$

Pericardial effusion $> 0.5\text{cm}$
Suggested sequence

1. Parasternal window
   
   Left ventricular long axis
   
   a. 2D examination of the left and right ventricles, left atrium and pericardium.
   
   b. M-mode of the left atrial size and left ventricular end diastolic dimension (LV volume) and fractional shortening (LV systolic function)
   
   c. Colour flow Doppler of the aortic and mitral valves

   Right ventricular inflow view
   
   a. 2D and colour flow Doppler assessment of the tricuspid valve.

   Left ventricular short axis of the aortic valve
   
   a. 2D and colour flow Doppler assessment of the aortic, tricuspid and pulmonary valves
   
   b. Interatrial septum position and motion (estimation of left atrial pressure).

   Left ventricular short axis midpapillary
   
   a. Left ventricular end diastolic area (left ventricular volume)
   
   b. Fractional area change (LV systolic function)

2. Apical window
   
   4-5 chamber view
   
   a. 2D and colour flow Doppler assessment of the aortic, mitral and tricuspid valves.
   
   b. Cardiac output is optional

   2-3 chamber for confirmation of aortic and mitral valves, left ventricular systolic function (including regional wall motion abnormalities).

3. Subcostal window
   
   a. 2D and colour flow Doppler assessment of the aortic, mitral and tricuspid valves.
   
   b. Interatrial septal motion (left atrial pressure)
   
   c. Inferior vena cava size and collapsibility with sniffing or deep inspiration.
APPENDIX 2  HEARTscan report form.
APPENDIX 3  Research questionnaires - Preoperative clinic study

Question sheet 1 - PRIOR TO ECHOCARDIOGRAPHY

Date  ___ / ___ / 2009
Study number  __________
Listed operation  

Indication for TTE (select most important indication)
- asymptomatic >65 y.o.
- abnormal cardiac test
- known cardiac disease
- unable to exercise
- cardiac symptoms
- suspected pulmonary hypertension or R heart failure
- murmur
- previous perioperative cardiac complications

If the patient was not involved in the study would you:
- Y  □ N order a TTE preop?
- Y  □ N request a cardiology consultation preop?
- Y  □ N delay surgery for other reasons - please specify

If no echo is available prior to surgery please indicate your anaesthesia plan:

<table>
<thead>
<tr>
<th>Anaesthesia Plan</th>
<th>Airway</th>
</tr>
</thead>
<tbody>
<tr>
<td>- General anaesthesia</td>
<td>LMA</td>
</tr>
<tr>
<td>- Regional anaesthesia</td>
<td>ETT</td>
</tr>
<tr>
<td>- Combined GA/regional</td>
<td>supplemental oxygen</td>
</tr>
<tr>
<td>- other - specify:</td>
<td>other - specify:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Induction</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>- intravenous</td>
<td>TIVA</td>
</tr>
<tr>
<td>- inhalational</td>
<td>inhalational agent</td>
</tr>
<tr>
<td>- other - specify:</td>
<td>other - specify:</td>
</tr>
</tbody>
</table>

Regional anaesthesia
- local infiltration
- peripheral nerve block
- peripheral nerve catheter
- spinal
- epidural
- other - specify:

Additional haemodynamic support
- vasopressor infusion
- inotrope infusion
- other - specify:

Intraoperative monitoring
- standard non-invasive monitoring only (SpO2, 3 lead ECG, NIBP, ETCO2)
- arterial line
- central venous pressure
- 5 lead ECG
- pulmonary artery catheter
- transoesophageal echocardiography
- transthoracic echocardiography
- other (specify):

Postoperative Care
- Standard ward
- Increased observations on standard ward (eg. FOU, SHU, ward+telemetry)
- High Dependency unit (HDU)
- Intensive Care unit (ICU)
After reviewing the HEARTscan results would you:
1. Y N request a cardiology consultation preop?
2. Y N request a cardiology consultation postop?
3. Y N request another specialist consultation? (eg. respiratory cause of symptoms)
4. Y N where you reassured of no significant cardiac pathology on echo?

Did the TTE affect the surgery?
1. Y N cancel the procedure eg. too high cardiac risk
2. Y N change the operation eg. perform less invasive procedure
3. Y N additional procedure eg. drain effusion or cardiac surgery specify:

Please fill in your current anaesthesia plan given the echo findings:

<table>
<thead>
<tr>
<th>Anaesthesia Plan</th>
<th>Airway</th>
</tr>
</thead>
<tbody>
<tr>
<td>General anaesthesia</td>
<td>LMA</td>
</tr>
<tr>
<td>Regional anaesthesia</td>
<td>ETT</td>
</tr>
<tr>
<td>Combined GA/regional</td>
<td>supplemental oxygen</td>
</tr>
<tr>
<td>other - specify:</td>
<td>other - specify:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Induction</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>intravenous</td>
<td>TIVA</td>
</tr>
<tr>
<td>inhalational</td>
<td>inhalational agent</td>
</tr>
<tr>
<td>other - specify:</td>
<td>other - specify:</td>
</tr>
</tbody>
</table>

Regional anaesthesia
1. local infiltration
2. peripheral nerve block
3. peripheral nerve catheter
4. spinal
5. epidural
6. other specify:

Additional haemodynamic support
1. vasopressor infusion
2. inotrope infusion
3. other - specify:

Intraoperative monitoring
1. standard non-invasive monitoring only (SpO2, 3 lead ECG, NIBP, ETCO2)
2. arterial line
3. central venous pressure
4. 5 lead ECG
5. pulmonary artery catheter
6. transoesophageal echocardiography
7. transthoracic echocardiography
8. other (specify):

Postoperative Care
1. Standard ward
2. Increased observations on standard ward (eg. FOU, SHU, ward+telemetry)
3. High Dependency unit (HDU)
4. Intensive Care unit (ICU)
Question sheet 3 - AFTER SURGERY

Date: __ / __ / 2009
Study number: _______

☐ Y ☐ N  Was surgery delayed?
   if yes: why?
☐ Y ☐ N  Did the HEARTscan echo change management in theatre?
   if yes: how?
☐ Y ☐ N  Was there a haemodynamic problem in theatre requiring more than usual treatment expected for the anaesthesia and surgery?
   problem(s):      treatment(s):
   □ hypotension    □ fluids
   □ tachycardia    □ vasoconstrictor
   □ dysrhythmia    □ inotrope
   □ other-specify: □ additional invasive monitoring
                     □ other-specify:
☐ Y ☐ N  Was there a haemodynamic problem postop requiring more than usual treatment expected for the anaesthesia and surgery?
   problem(s):      treatment(s):
   □ hypotension    □ fluids
   □ tachycardia    □ vasoconstrictor
   □ dysrhythmia    □ inotrope
   □ other-specify: □ additional invasive monitoring
                     □ upgrade in postop care eg. HDU
                     □ other-specify:

Anaesthesia management
☐ General anaesthesia
☐ Regional anaesthesia
☐ Combined GA/regional
☐ other - specify:

Airway
☐ LMA
☐ ETT
☐ supplemental oxygen
☐ other - specify:

Induction
☐ intravenous
☐ inhalational
☐ other - specify:

Maintenance
☐ TIVA
☐ inhalational agent
☐ other - specify:

Regional anaesthesia
☐ local infiltration
☐ peripheral nerve block
☐ peripheral nerve catheter
☐ spinal
☐ epidural
☐ other - specify:

Intraoperative monitoring
☐ standard non-invasive monitoring
☐ arterial line
☐ central venous pressure
☐ 5 lead ECG
☐ pulmonary artery catheter
☐ TOE
☐ transthoracic echocardiography
☐ other (specify):

Postoperative Care
☐ Standard ward
☐ Increased observations on standard ward (eg. FOU, SHU, ward + telemetry)
☐ High Dependency unit (HDU)
☐ Intensive Care unit (ICU)
Question sheet 1 - PRIOR TO ECHOCARDIOGRAPHY

Indication(s) for TTE
You may tick more than one option

☐ haemodynamic instability
☐ cardiac disease signs
☐ cardiac disease symptoms
☐ murmurs
☐ asymptomatic, >65 y.o.
☐ abnormal cardiac test
☐ can’t assess functional state, suspect cardiac dx
☐ known cardiac disease, ?deterioration
☐ previous perioperative cardiac complications

In your opinion what is the most important indication?

☐ haemodynamic instability
☐ cardiac disease signs
☐ cardiac disease symptoms
☐ murmurs
☐ no significant cardiac disease suspected, >65 y.o.
☐ abnormal cardiac test
☐ can’t assess functional state, suspect cardiac dx
☐ known cardiac disease, ?deterioration
☐ previous perioperative cardiac complications

What is the principle haemodynamic state?

☐ Normal
☐ Empty
☐ Vasodilated
☐ LV Systolic
☐ Primary LV diastolic failure
☐ LV Systolic and diastolic failure
☐ RV failure
☐ Unsure

Do you think there is a valvular or other sig. cardiac abnormality?

☐ Yes  ☐ No

<table>
<thead>
<tr>
<th>Valvular Abnormality</th>
<th>Haemod. Significant</th>
<th>Not Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic</td>
<td>AR ☐ AS ☐</td>
<td></td>
</tr>
<tr>
<td>Mitral</td>
<td>MR ☐ MS ☐</td>
<td></td>
</tr>
<tr>
<td>Tricuspid</td>
<td>TR ☐ TS ☐</td>
<td></td>
</tr>
<tr>
<td>Pulmonary</td>
<td>PR ☐ PS ☐</td>
<td></td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Pulmonary embolus</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Other: please specify:
**Question sheet 2 - PRIOR TO ECHOCARDIOGRAPHY**

**What is your preop plan?**
- Proceed regardless of TTE
- Defer for further investigations or consultations
- Cancel surgery
- Proceed with a change in the operation:
  - specify:

**Anaesthesia Plan**
- General anaesthesia
- Regional anaesthesia
- Combined GA/regional
- other - specify:

**Induction**
- intravenous
- inhalational
- other - specify:

**Regional anaesthesia**
- local infiltration
- peripheral nerve block
- peripheral nerve catheter
- spinal
- epidural
- other - specify:

**Airway**
- LMA
- ETT
- supplemental oxygen
- other - specify:

**Maintenance**
- TIVA
- inhalational agent
- other - specify:

**Additional haemodynamic support**
- fluid bolus pre induction
- inotrope infusion
- GTN/vasodilator
- vasopressor infusion
- vasopressor boluses PRN
- other - please specify:

**Additional Intraoperative monitoring**
- arterial line
- central venous pressure
- TOE
- TTE
- 5 lead ECG
- pulmonary artery catheter
- other (specify)

**Postoperative Care**
- Standard ward
- High Dependency unit (HDU)
- Intensive Care unit (ICU)
**What is your preop plan given the echo information?**
- Proceed
- Defer for further investigations or consultations
- Cancel surgery
- Proceed with a change in the operation:
  - specify:

**Anaesthesia Plan**
- General anaesthesia
- Regional anaesthesia
- Combined GA/regional
- other - specify:

**Airway**
- LMA
- ETT
- supplemental oxygen
- other - specify:

**Induction**
- intravenous
- inhalational
- other - specify:

**Maintenance**
- TIVA
- inhalational agent
- other - specify:

**Regional anaesthesia**
- local infiltration
- peripheral nerve block
- peripheral nerve catheter
- spinal
- epidural
- other - specify:

**Additional haemodynamic support**
- fluid bolus pre induction
- inotrope infusion
- GTN/vasodilator
- vasopressor infusion
- vasopressor boluses PRN
- other - please specify:

**Additional Intraoperative monitoring**
- arterial line
- central venous pressure
- TOE
- TTE
- 5 lead ECG
- pulmonary artery catheter
- other (specify)

**Postoperative Care**
- Standard ward
- High Dependency unit (HDU)
- Intensive Care unit (ICU)
APPENDIX 5  Research Grants, Presentations and awards

Research Grants

1. Australian and New Zealand College of Anaesthetists Project grant and scholarship
   $140,000 over 3 years 2011-2013

Oral presentations

1. Invited speaker, ANZCA Rural Anaesthesia Special Interest Group 8/7/2012
   Torquay, Victoria, Australia
   “Guiding perioperative management decisions with echo”

2. PhD presentation, University of Melbourne Cardiovascular Research Domain 22/6/2012
   University of Melbourne, Parkville, Victoria, Australia
   “The Impact of Focused Transthoracic Echocardiography in Non-cardiac Anaesthesia and Surgery.”

Poster presentations

1. Prize for best student scientific poster, ANZCA Cardiothoracic, Vascular and Perfusion Special Interest Group Biennial Meeting (CVP SIG) 6/10/09
   Noosa, Queensland, Australia
   “Audit of anaesthetist-performed echocardiography on perioperative management decisions for non-cardiac surgery.”

2. Prize for best student scientific poster, Melbourne Health Research Week 17/6/2010
   Royal Melbourne Hospital, Parkville, Victoria, Australia
   “The impact of transthoracic echocardiography performed by anaesthetists immediately prior to emergency surgery, on perioperative decision-making.

3. Poster presentation, ANZCA CVP SIG Biennial Meeting  3/10/2011
   Hamilton Island, Queensland, Australia
   “The impact of anaesthetist performed transthoracic echocardiography in a preoperative clinic on perioperative decision-making.”
4. **Poster presentations.** Combined meeting of the 13\textsuperscript{th} International Congress of Cardiothoracic and Vascular Anesthesia/ANZCA/New Zealand College of Anaesthetists 17/11/2012.

Auckland, New Zealand

i) “The impact of focused transthoracic echocardiography in the pre-operative clinic”

ii) “The impact of pre-operative focused transthoracic echocardiography in emergency non-cardiac surgery patients with known or risk of cardiac disease”

References

2. Kneeshaw JD. Transoesophageal echocardiography (TOE) in the operating room. *British Journal of Anaesthesia* 2006; 97:77-84.


31. Nazarian LN. The top 10 reasons musculoskeletal sonography is an important complementary or alternative technique to MRI. *American Journal of Roentgenology* 2008; **190**:1621-6.


42. Kimura BJ, Shaw DJ, Agan DL, Amundson SA, Ping AC, DeMaria AN. Value of a cardiovascular limited ultrasound examination using a hand-carried ultrasound device on...


47. Royse CF, Royse AG, Soeding PF, Blake DW. Shape and movement of the interatrial septum predicts change in pulmonary capillary wedge pressure. *Annals of Thoracic and Cardiovascular Surgery* 2001; **7**:79-83.


110. Blaivas M, Fox JC. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Academy of Emergency Medicine* 2001; 8:616-21.


188. Sharrock NE. Fractured femur in the elderly: intensive perioperative care is warranted. *British Journal of Anaesthesia* 2000; **84**:139-40.


199. Levy N. A study of the initial fluid resuscitation and pain management of patients with fractured neck of femur. *Anaesthesia* 2002; **57**:1148-.


205. Cowie BS. Does the pulmonary artery catheter still have a role in the perioperative period? Anaesthesia & Intensive Care 2011; 39:345-55.


209. Esophageal Doppler ultrasound-based cardiac output monitoring for real-time therapeutic management of hospitalized patients - a review. Agency For Health Research and Quality 2007, Rockville, Maryland.


