Repeated Monitoring With Transthoracic Echocardiography and Lung Ultrasound After Cardiac Surgery: Feasibility and Impact on Diagnosis

Ahmed Alsaddique, MD,* Alistair G. Royse, MD,†‡ Colin F. Royse, MD,†‡ Abdulelah Mobeirek, MD,* Fayez El Shaer, MD,* Hanan AlBackr, MD,* Mohammed Fouda, MD,* and David J. Canty, PhD†‡

Objectives: **Cardiorespiratory complications are common after cardiac surgery and current monitors used to diagnose these are invasive and have limitations. Transthoracic echocardiography and lung ultrasound are noninvasive and frequently improve diagnosis in critically ill patients but have not been reported for routine postoperative monitoring after coronary, valve, and aortic surgery. The aim was to determine whether both repeated postoperative transthoracic echocardiography and lung ultrasound revealed or excluded clinically important cardiac and respiratory disorders compared to conventional monitoring and chest x-ray.**

Design: **Prospective observational study.**

Setting: **Tertiary university hospital.**

Participants: **Ninety-one patients aged older than 18 undergoing cardiac surgery**

Interventions: **Postoperative clinical patient assessment for significant cardiac and respiratory disorders by the treating physician was recorded at 3 time points (day after surgery, after extubation and removal of chest drains and at discharge) using conventional monitoring and chest x-ray. After each assessment, transthoracic echocardiography and lung ultrasound were performed, and differences in diagnosis from conventional assessment were recorded.**

Measurements and Main Results: **Transthoracic echocardiography was interpretable in at least 1 echocardiographic window in 99% of examinations. Transthoracic echocardiography and/or lung ultrasound changed the diagnosis of important cardiac and/or respiratory disorders in 61 patients (67%). New cardiac findings included cardiac dysfunction (38 patients), pericardial effusion (5), mitral regurgitation (2), and hypovolemia (1). New respiratory findings included pleural effusion (30), pneumothorax (4), alveolar interstitial syndrome (3) and consolidation (1).**

Conclusions: **Routine repeated monitoring with cardiac and lung ultrasound after cardiac surgery is feasible and frequently alters diagnosis of clinically important cardiac and respiratory pathology.**

KEY WORDS: echocardiography, lung, ultrasound, surgery complications, postoperative care

ACCURATE AND RESPONSIVE cardiac and respiratory monitoring of patients after cardiac surgery in the intensive care unit (ICU) is important as these patients commonly have little physiologic reserve and are subjected to significant hemodynamic stress, and cardiac and respiratory complications are common. Limitations of currently used invasive pressure and flow monitors include inability to diagnose the cause of hemodynamic disturbance[1,2] and potential for harm.[3] Transesophageal echocardiography (TEE) improves diagnosis,[4] but its use is restricted by operator expertise, patient sedation, and risk of potentially lethal complications.[5] The usefulness of repeated routine chest x-rays has been questioned in the ICU[6] and in postoperative cardiothoracic surgery patients,[7] which expose patients and staff to harmful ionizing radiation.

Transthoracic echocardiography (TTE) is noninvasive and provides diagnosis of the etiology of shock in patients admitted to the intensive care unit (ICU), alters management,[8,9] may improve outcome,[10] and is being incorporated into ICU practice.[11] However, impact of TTE on diagnosis as a monitor (screening) in the ICU is not reported, neither has its impact on diagnosis after cardiac surgery, presumably due to poor image quality from ultrasound interference caused by mediastinal air, surgical drains and dressings.[12,13] However, good TTE image quality has been reported after aortic valve replacement.[14]

Lung ultrasound (LU) is more accurate than chest x-ray and approaches the accuracy of computed tomography in the bedside diagnosis of pleural effusion, pneumothorax, pulmonary edema, consolidation and collapse, abscess, emphysema, and even pulmonary embolus.[15] LU also is being adopted in critical care practice[16] where it can be performed at the same time as TTE. In some situations, it has substituted chest x-ray and CT, reducing exposure to ionizing radiation.[17]

The authors' hypothesis was that routine and repeated monitoring with TTE and LU performed at 3 time points after cardiac surgery is *feasible* and *changes the diagnosis* of clinically important cardiac and respiratory abnormalities compared with clinical assessment, conventional monitoring, and review of chest x-ray by the treating physician.

METHODS

This prospective observational study received ethics approval from the King Saud University Health System (Riyadh, Saudi Arabia) and the Melbourne Health Human Ethics Committee (Australia). Patients presenting for cardiac surgery between July 2011 and August 2012 at The King Fahad Cardiac Center of King Saud University were screened for inclusion (convenience sampling) by research personnel. Inclusion criteria included patients older than 18 and informed consent from the patient or legal guardian. There were no exclusion criteria. The study was not performed at the Royal Melbourne Hospital due to lack of available research personnel.

General Conduct of the Study and Study Endpoints

Data were obtained at 3 time points (Fig 1): T1 on the first day after surgery (in the ICU), T2 after extubation and removal

*From the *King Fahad Cardiac Center and College of Medicine, King Saud University, Riyadh, Saudi Arabia; †Department of Surgery, University of Melbourne, Royal Parade, Parkville, Australia; and ‡Royal Melbourne Hospital, Grattan Street, Parkville, Australia.*

Please address reprint requests to David J. Canty, PhD, Ultrasound Education Group, Department of Surgery, Level 6 Centre for Medical Research, University of Melbourne, Royal Parade, Parkville, Victoria, Australia 3050. E-mail: dj_canty@hotmail.com

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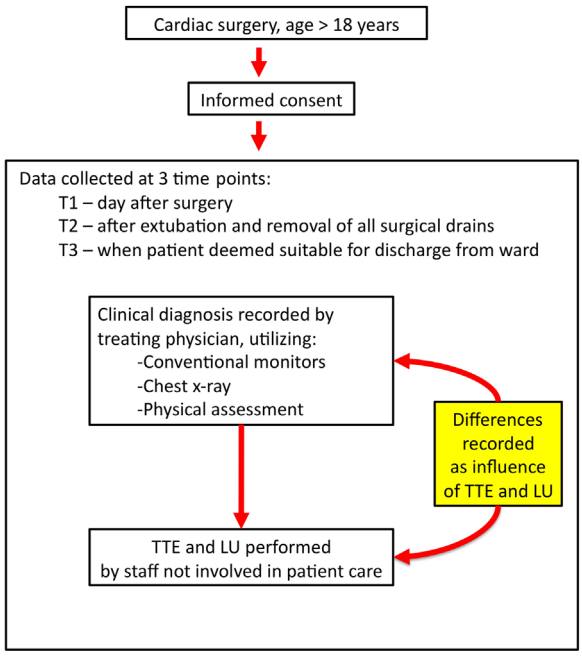

Fig 1. Study conduct. TTE, transthoracic echocardiography; LU, lung ultrasound.

of all pleural and mediastinal surgical drains (in the ICU or on the ward), and T3 when the patient was deemed medically fit for discharge from the general ward. At each time point, after review of all available conventional monitors and chest x-ray performed that morning, the treating physician recorded their assessment of defined significant cardiac and respiratory pathology on a research form. As soon as practical after these assessments, TTE and LU were performed by qualified technicians not involved in patient care, who recorded their findings on a standardized report form (Appendix A). The technicians also recorded their assessment of image quality of TTE. The primary endpoint was a difference in diagnosis of clinically important cardiac and respiratory abnormalities between the clinical assessment and ultrasound (TTE and LU). Ultrasound was considered the gold standard in diagnosis. As the diagnostic plan was recorded before and after ultrasound, patients acted as their own controls. The secondary endpoint was the TTE image quality.

Surgery and Perioperative Monitoring

Surgical access was by median sternotomy. Two subxyphoid mediastinal drains were inserted and usually removed on the first postoperative day. Pleural drains were inserted when the pleura was breached and usually removed on the second postoperative day. Intraoperative TEE was performed routinely in all patients before and after surgery by a cardiologist with board certification and suitable training and experience in perioperative TEE. Routine (conventional) monitoring used during and after surgery included arterial, central venous and pulmonary artery pressures, intermittent cardiac output by pulmonary artery thermodilution, pulmonary capillary wedge pressure, 5-lead electrocardiogram, pulse oximetry, and capnography.

Definitions of Ultrasound and Clinical Assessment of Cardiac and Respiratory Pathology

Significant cardiac abnormalities were defined for both clinical and TTE assessment as those that could result in hemodynamic instability after surgery. This included 1 or more of the following: an abnormal hemodynamic state (as described by Royse[18] and summarized below), valve stenosis or regurgitation of at least moderate severity according to recognized guidelines,[19,20] and a pericardial effusion greater than 0.5 cm.

Using TTE, the hemodynamic state was classified into 1 of 7 (normal, empty, vasodilated, left ventricular systolic dysfunction, left ventricular diastolic dysfunction, left ventricular systolic and diastolic dysfunction, and right ventricular dysfunction) based on the assessment of LV volume (end-diastolic dimension or area), LV systolic function (change in LV cavity dimension or area), and left atrial pressure (interatrial septal motion), which was adapted from Royse[18] and summarized in Table 1.

Clinical assessment of valve stenosis and regurgitation was defined in the same way as TTE (at least moderate severity). Clinical assessment of a hemodynamically significant pericardial effusion was left to the methods used by the treating physician (eg, pulsus paradoxus, raised jugular venous pulse, and reduced heart sounds). Clinical assessment of the hemodynamic state was defined in the same manner as TTE assessment. However, unlike assessment with TTE, it is difficult to separate LV from RV dysfunction and LV systolic dysfunction from diastolic dysfunction using clinical assessment and conventional monitoring, as the signs and symptoms of ventricular dysfunction are common to these conditions. Right ventricular dysfunction, LV systolic dysfunction, and LV diastolic dysfunction were therefore combined and defined as cardiac dysfunction to enable comparison, as done previously.[21]

Respiratory abnormalities included pleural effusion, pneumothorax, consolidation or atelectasis, and alveolar interstitial syndrome. LU assessment of these conditions followed reported recommendations for performance and assessment of lung ultrasound.[16] Clinical assessments of these conditions were based on review of the chest x-ray by the treating physician, which was done routinely prior to each of the 3 assessments. Pleural effusion volume was estimated with lung ultrasound with published methods[22,23] but not with clinical examination. An estimated effusion volume of 500 mL was considered to be visible on chest x-ray[24] and was the cut-off value for comparison with clinical diagnosis.

Performance and Reporting of TTE and LU

Trained technicians supervised by board-certified cardiologists performed TTE on all patients in the supine position following the iHEARTscan™ protocol (Hemodynamic Echocardiography Assessment in Real Time),[25] a focused study designed to diagnose hemodynamically significant ventricular and valve disease and abnormal hemodynamic state. The protocol includes 2D and color-flow Doppler but not spectral Doppler and uses the parasternal, apical, and subcostal windows. The echocardiography protocol is designed to be performed in fewer than 10 minutes. They assessed the image