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Original Article

Evaluation of the Clinical Utility of Transesophageal Echocardiography and Invasive Monitoring to Assess Right Ventricular Function During and After Pulmonary Endarterectomy

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Objective: Patients undergoing pulmonary endarterectomy (PEA) have impaired right ventricular function. The authors sought to assess the clinical utility of commonly used perioperative echocardiographic and right heart catheter measurements in patients undergoing PEA.
Design: A single-center prospective observational study.
Setting: The study was conducted in a quaternary care cardiac surgical center in the United Kingdom.
Participants: Patients undergoing PEA between April 2015 and January 2016.
Interventions: Thermodilution cardiac index and echocardiography variables were measured at 3 time points: before sternotomy (T1), after pericardial incision (T2), and after sternal closure (T3). Six-month follow-up echocardiography and 6-minute walk (6-MWT) test were performed.
Measurements and Main Results: Fifty patients were recruited and complete data sets were available for 41 patients. Tricuspid annular plane systolic excursion declined after pericardial incision and cardiopulmonary bypass (T1: 15 $\pm$ 4 mm, T2: 13 $\pm$ 4 mm, T3: 7 $\pm$ 2 mm; $p < 0.0001$), returning to baseline 6 months postoperatively. Cardiac index (T1: 2.5 $\pm$ 0.7 L/min/m^2, T2: 2.6 $\pm$ 0.6 L/min/m^2, T3: 2.3 $\pm$ 0.5 L/min/m^2; $p = 0.07$) and right ventricular fractional area change (T1: 36 $\pm$ 11%, T2: 40 $\pm$ 12%, T3: 40 $\pm$ 9%; $p = 0.12$) were preserved perioperatively. 6-MWT improved from baseline (294 $\pm$ 111 m) to follow-up (357 $\pm$ 107 m) ($p < 0.001$). Pulmonary vascular resistance at T3 correlated moderately with follow-up 6-MWT ($R = -0.60$).

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Conclusions: In patients undergoing PEA, invasive measurements and echocardiography assessment of right ventricular function are not interchangeable. Tricuspid annular plane systolic excursion is not a reliable measure of right ventricular function perioperatively. Pulmonary vascular resistance shows moderate correlation with postoperative functional capacity.

Key Words: echocardiography; pulmonary endarterectomy; pulmonary hypertension; right ventricular function; tricuspid annular plane systolic excursion

CHRONIC THROMBOEMBOLIC pulmonary hypertension (CTEPH) develops as a complication in up to 3.8% of patients after an acute pulmonary embolism.[1] In these patients, progressive pulmonary vascular changes lead to pulmonary hypertension producing dyspnea, hypoxemia, and right heart failure.[2] Pulmonary endarterectomy (PEA) is the surgical treatment of choice for many patients with symptomatic CTEPH as it results in reduced pulmonary vascular resistance (PVR) and therefore improved symptoms and survival with a 2% to 5% in-hospital mortality rate.[3–7]

However, patients presenting for PEA have right ventricular (RV) hypertrophy, dilatation, and systolic dysfunction.[8] Transesophageal echocardiography (TEE) and pulmonary artery catheterization are standard practice intraoperatively during PEA and permit real-time assessment of RV function before and after cardiopulmonary bypass (CPB).[9] It has been suggested that RV function deteriorates immediately after PEA, demonstrated by reduced tricuspid annular plan systolic excursion (TAPSE) while elevated postoperative PVR and mean pulmonary artery pressure (mPAP) are associated with reduced long-term functional capacity and reduced survival.[4,10,11]

However, recent research has revealed the inaccuracy of the commonly used echocardiographic measures of RV systolic function in surgery where the pericardium has been opened. After pericardial opening, the pattern of RV contraction changes with increased radial contraction compensating for reduced longitudinal contraction.[12–15] It is unclear if these findings are pertinent in patients with CTEPH or if they are predictive of functional outcome.

The authors sought to assess the clinical utility of commonly used perioperative echocardiographic and right heart catheter measurements in patients undergoing PEA. Specifically, to determine (1) if TAPSE and RVFAC are reliable measures of RV function perioperatively in patients undergoing PEA when compared to thermodilution cardiac output studies; (2) if pulmonary artery acceleration time (PAAT) is useful surrogate for invasive mPAP or PVR; and (3) if intraoperative echocardiographic and right heart catheterization measures correlate to functional status at 6 months, measured with the 6-minute walk test (6-MWT).

Methods

Study Population and Protocol

After local Research and Ethics committee approval and obtaining informed consent, 50 patients undergoing PEA at a single center in the United Kingdom were enrolled prospectively over a 9-month period. Patients were excluded if they had contraindications to TEE, previously had undergone cardiac surgery, or reduced left ventricular systolic function on preoperative planning transthoracic echocardiography (TTE) (defined as left ventricular ejection fraction less than 55%).

Anesthetic Management

Patients received a standardized anesthetic with full invasive monitoring including radial and femoral arterial monitoring, central venous catheterization, pulmonary artery catheterization, and TEE.[9] Thermodilution cardiac output studies using room temperature 5% dextrose were performed as the average of 3 results to measure cardiac index (CI). Cardiac output and TEE studies were undertaken simultaneously at 3 time points: prior to sternotomy (T1), 5 minutes after pericardiotomy (T2), and following chest closure (T3). Additionally, hemodynamic parameters including heart rate, mean arterial pressure (MAP), central venous pressure (CVP), and mPAP were recorded at each time point. PVR was calculated with an assumed pulmonary artery wedge pressure of 10 mmHg, as it is local policy not to wedge the pulmonary catheter in patients undergoing this procedure to reduce the risk of pulmonary artery rupture.[16] Systemic vascular resistance (SVR) was calculated using measured MAP and CVP. Inotropic support was used at the discretion of the attending anesthesiologist. All patients underwent standard PEA surgery with CPB and deep hypothermic circulatory arrest as previously described.[17,18]

Echocardiographic Assessment

Once the patient was anesthetized and before surgery commencing, a TEE examination was performed by an anesthesiologist accredited in perioperative TEE using Philips iE33 or Epiq7 machines and an X7 TEE probe (Philips Medical Systems, Andover, MA). In addition to the standard TEE views, the intraoperative echocardiography study protocol included collection of the following images:

1. Midesophageal 4-chamber view of the right ventricle used to measure RV fractional area change (RVFAC).[19]
2. A modified transgastric RV inflow view (Fig 1) to obtain TAPSE using M-mode to optimize alignment of the tricuspid annulus with the M-mode cursor.
3. Pulse wave Doppler assessment of flow in the proximal pulmonary artery within 2 cm of the pulmonary valve from

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