Unilateral Postoperative Pulmonary Edema After Minimally Invasive Cardiac Surgical Procedures: A Case-Control Study

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Background. **Unilateral postoperative pulmonary edema is an underreported adverse event after a minimally invasive cardiac surgical procedure that combines right minithoracotomy with cardiopulmonary bypass. We sought to characterize its incidence, risk factors, and morbidity.**

Methods. **We conducted a retrospective case-control study of all cardiac surgical procedures that combined right-sided minithoracotomy with cardiopulmonary bypass at our institution over 8 consecutive years. Unilateral postoperative pulmonary edema was defined on the chest radiograph taken on the first postoperative day as relatively increased opacification of the right versus left hemithorax involving at least 20% of the hemithorax, not better explained by atelectasis. Baseline characteristics, potential risk factors, and outcomes were subject to univariable and multivariable analysis.**

Results. **Radiographs were available for 277 of 278 patients; of those, 68 (25%) met our definition of unilateral postoperative pulmonary edema. Patients with unilateral postoperative pulmonary edema had higher mortality and were more likely to have a lower postoperative PaO_2/F_IO_2 ratio, to require vasoactive medications and mechanical ventilation for longer than 24 hours, and to have longer lengths of stay in the intensive care unit and the hospital. Unilateral postoperative pulmonary edema was independently associated with chronic obstructive pulmonary disease (odds ratio [OR] 4.79; 95% confidence interval [CI] 1.28 to 18.0; $p = 0.02$); pulmonary hypertension, right-ventricular dysfunction, or both (OR 2.92; 95% CI 1.41 to 6.03; $p = 0.004$); and increasing cardiopulmonary bypass time (OR 1.019; 95% CI 1.011 to 1.027 per additional minute; $p < 0.001$).**

Conclusions. **Unilateral postoperative pulmonary edema after minimally invasive cardiac surgical procedures is common, carries significant morbidity, and has identifiable risk factors. Further research is needed to enable a better understanding of the pathophysiology and clinical implications of unilateral postoperative pulmonary edema.**

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Minimally invasive cardiac surgical procedures often use a right minithoracotomy approach, one-lung ventilation, and cardiopulmonary bypass (CPB) through cannulation of peripheral vessels, typically the femoral artery or vein and the superior vena cava (SVC). Increased radiographic opacification of the right versus the left lung in the immediate postoperative period has been observed in several patients undergoing right minithoracotomy for minimally invasive cardiac surgical procedures at our institution. Several of these patients experienced significant adverse events. The opacification we have observed is phenotypically similar to reexpansion pulmonary edema, a rare adverse event after rapid lung reexpansion (Fig 1).

Reexpansion pulmonary edema most commonly occurs after decompression of significant pneumothoraces or rapid tube thoracostomy drainage of large, chronic pleural effusions [1, 2]. Reexpansion edema is rarely reported perioperatively [3]. The unilateral postoperative pulmonary edema we observed was associated with increased morbidity, including significant endotracheal secretions, hypoxemia, ventilatory insufficiency, and hemodynamic instability.

Two previous case reports described reexpansion edema after minimally invasive cardiac surgical procedures [3, 4]. One followed a minimally invasive aortic valve surgical procedure, and the other followed a minimally invasive mitral valve surgical procedure. In both cases the patients survived; however, their course was complicated by marked unilateral

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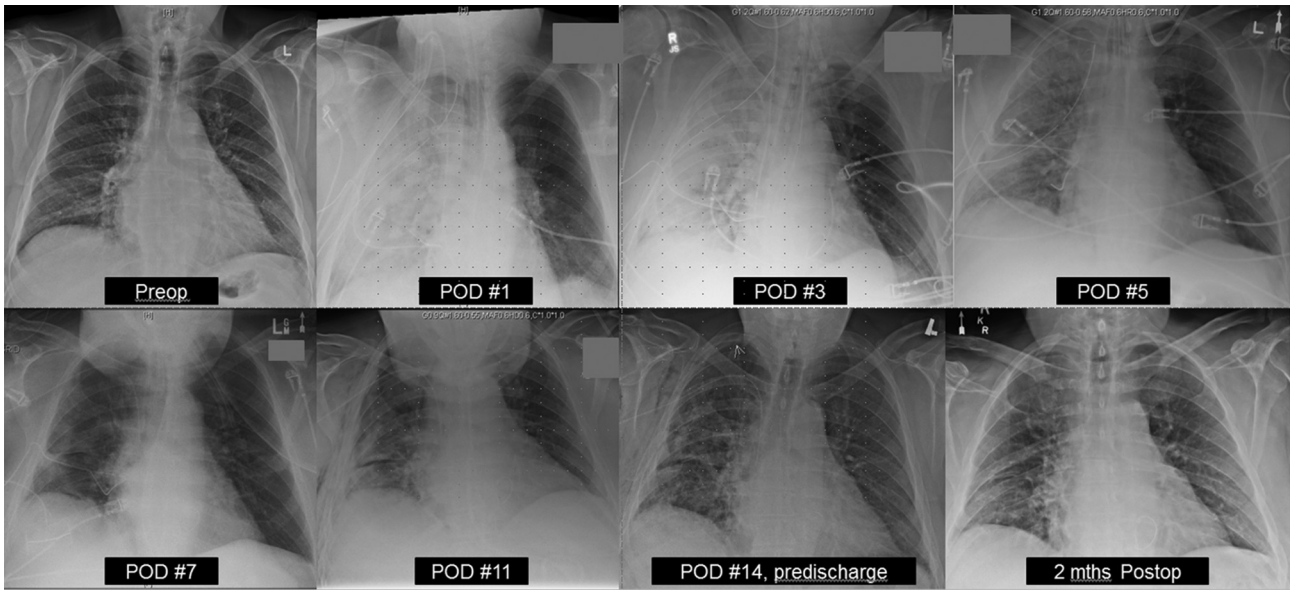

Fig 1. Serial chest radiographs of a 67-year-old patient with moderate chronic obstructive pulmonary disease, significant pulmonary hypertension (right ventricular systolic pressure: 76/22 mm Hg), and obesity who underwent a minimally invasive mitral valve repair for Barlow's disease. He experienced acute, unilateral, postoperative pulmonary edema shortly after returning to the intensive care unit. The serial chest radiographs demonstrate significant right lung opacification between the first and third postoperative days, with interval resolution thereafter. (Preop = preoperative; POD = postoperative day.)

lung edema requiring extracorporeal membrane oxygenation.

Our anecdotal experience suggested that unilateral pulmonary edema after minimally invasive cardiac surgical procedures represented an underrecognized adverse event of this surgical approach. Furthermore, we hypothesized that unilateral lung edema in patients undergoing minimally invasive cardiac surgical procedures has important clinical consequences. Therefore, we designed an observational case-control study with the following objectives: (1) to describe the incidence of unilateral pulmonary edema after minimally invasive cardiac surgical procedures involving a right thoracotomy and CPB, (2) to identify risk factors associated with unilateral postoperative pulmonary edema, and (3) to characterize the clinical importance of this finding.

Patients and Methods

This study was conducted in accordance with the consensus guidelines expressed by the STROBE statement [5]. Approval was obtained from Western University's Ethics Board before data collection was begun. Data were obtained for all cardiac surgical procedures combining a right-sided minithoracotomy approach with CPB bypass from January 1, 2005, to December 31, 2012. Surgical procedures undertaken before 2005 were excluded because radiographs before this period were no longer archived by our institution.

Baseline and perioperative clinical data were collected by a single reviewer (MT) directly from the patients' records or from a prospectively collected database maintained by the Division of Cardiac Surgery. Demographic data, medical history, echocardiographic parameters, perioperative factors, and outcome data were included.

Outcomes

Our primary outcome was defined as a relative increase in right-sided versus left-sided opacification of the hemithorax occupying more than 20% of the chest field, not better explained by atelectasis. This criterion was selected because we thought it would exclude the majority of cases of routine postoperative atelectasis, pulmonary contusion, or both. Atelectasis was considered the cause of radiographic change when opacification occurred exclusively in dependent lung zones or when it followed a typical narrow, segmental pattern. The primary outcome was determined from the chest radiograph taken on the first postoperative day. When no radiograph was available from the first postoperative day, the first available postoperative radiograph was substituted. Patients with no postoperative imaging were excluded. Chest radiographs were independently reviewed by two reviewers (MT, DB, or PJ). Radiographs were deemed positive or negative for the primary outcome when there was initial agreement between both reviewers. When the reviewers disagreed, the primary outcome was adjudicated by consensus during a second review conducted by three reviewers (MT, DB, PJ). The reviewers were blinded to study data until after the radiographic findings were adjudicated. The routine clinical practice of all reviewers included daily interpretation of chest radiographs from patients undergoing cardiac surgical procedures. All