Lung Volume Reduction Surgery on Extracorporeal Life Support

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Lung volume reduction surgery improves exercise tolerance, lung function, and quality of life for selected patients with emphysema. Lung volume reduction surgery is well established for patients in a highly elective setting. It is, however, contraindicated in cases of acute cardiorespiratory failure. We present the case of a patient with severe emphysema who had acute respiratory failure and decompensated cor pulmonale requiring life-saving venovenoarterial extracorporeal life support after admission to the emergency unit. He underwent lung volume reduction surgery with intent to wean from extracorporeal life support. He had complete functional recovery after 4 months.

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Since the reintroduction of lung volume reduction surgery (LVRS) by Cooper and colleagues [1] in 1995, numerous articles reported its efficacy for selected patients with severe emphysema. However, the use of LVRS has been generally considered contraindicated in the setting of acute respiratory failure. Here, we report a successful case of LVRS performed on a patient on extracorporeal life support (ECLS).

A 33-year-old man with emphysema related to tobacco, marijuana, and cocaine inhalation was evaluated in our outpatient clinic for LVRS because of slowly decreasing exercise tolerance that impaired his quality of life. His arterial blood gas analysis on room air showed the following: pH 7.41; partial oxygen pressure 6.9 kPa (52 mm Hg); partial carbon dioxide pressure in arterial blood gas 5.8 kPa (43.5 mm Hg); oxygen saturation 90%; and bicarbonate (HCO3−) 26.3 mmol/L. The 6-minute walk test revealed a walking distance of 450 m, initial peripheral oxygen saturation (Spo_2) 89%, initial heart rate 61 beats per minute, final Spo_2 86%, final heart rate 92 beats per minute, and moderate physical exhaustion. Pulmonary function tests showed the following after bronchodilation (percent of predicted value): forced vital capacity (FVC) 3.74 L (76%); forced expiratory volume in 1 second (FEV_1) 1.56 l (38%); FEV_1/FVC 42%; total lung capacity (TLC) 10.14 L (147%); residual volume (RV) 6.44 L (369%); RV/TLC 63% (234%); and diffusing capacity of lung for carbon monoxide 5.54 mmol · min^{-1} · kPa^{-1} (49%). Computed tomography is shown in Figure 1. Echocardiography revealed a dilated right ventricle, a moderate tricuspid insufficiency with an estimated systolic pulmonary artery pressure of 55 mm Hg. An elective bilateral video-assisted LVRS was recommended but was not performed because the patient did not stop smoking.

Eighteen months later, the patient was found unconscious at home probably from a drug overdose. He was intubated on site and brought to the emergency department. On arrival, his systolic blood pressure was 90 mm Hg with dobutamine and low-dose norepinephrine support, his heart rate was 95 beats per minutes, and Spo_2 was 75% with fraction of inspired oxygen of 100%. Computed tomography showed bilateral lower lobe consolidations and upper-lobe predominance of emphysema with flattening of both diaphragms. A decompensated cor pulmonale was suspected owing to the enlarged pulmonary trunk, right ventricle, and right atrium, with contrast back flow into the enlarged inferior vena cava. Echocardiography showed D-shaping of the interventricular septum. Bronchoscopy showed thick secretions from both lower lobes. Piperacillin, tazobactam, and clarithromycin antimicrobial therapy was started empirically. Arterial blood gas showed the following results with maximal ventilatory support: pH 7.21; partial oxygen pressure 5.26 kPa (39 mm Hg); partial carbon dioxide pressure 10.5 kPa (78.7 mm Hg); hemoglobin oxygen saturation 63%; and bicarbonate 31.1 mmol/L.

Facing the persistence of hemodynamic and respiratory failure, a femorofemoral venoarterial ECLS was implanted to unload the right ventricle. An additional venous supply cannula (venovenoarterial ECLS) was required in the jugular vein to improve oxygenation. The next day and the day after that, right-sided and left-sided LVRS of both upper lobes was sequentially performed through anterior thoracotomies. Downgrading of the venovenoarterial ECLS to femorojugular venovenous ECLS and tracheostomy were performed on day 5 after the first LVRS. The patient was weaned from ECLS and mechanical ventilation on day 8 and 13, respectively, after the first LVRS. The tracheostomy cannula was removed 3 weeks after LVRS, and the patient discharged to a rehabilitation clinic 5 weeks after LVRS. Postoperative left-sided foot flexor paresis limited his walking distance.

The patient was free of respiratory symptoms 4 months after LVRS. Arterial blood gas on room air showed the following: pH 7.43; partial oxygen pressure 9.9 kPa (74.2 mm Hg); partial carbon dioxide pressure 5.3 kPa (39.7 mm Hg); hemoglobin oxygen saturation 96%; and bicarbonate 26.3 mmol/L. The 6-minute walk test showed 375 m walking distance, initial Spo_2 95%, initial heart rate 67

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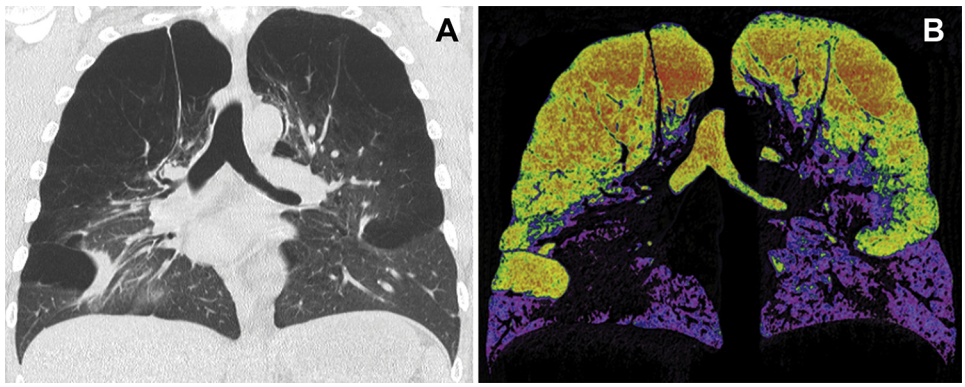

Fig 1. Chest computed tomography 18 months before lung volume reduction surgery showing (A) upper-lobe predominance of emphysema in lung window and (B) densitometry. Hypodense (emphysematous) and hyperdense (healthy/compressed) lung parenchyma appear red and violet-blue, respectively. Note the flattening of both diaphragms.

beats per minute, final Spo_2 93%, final heart rate 80 beats per minute, and light exhaustion. (Note the postoperative shorter walking distance due to foot flexor paresis.) Pulmonary function tests showed the following after bronchodilation: FVC 5.3 l (109%), FEV_1 3.98 l (98%)' FEV_1/FVC 70%, TLC 7.47 l (108%); RV 2.1 l (118%); RV/TLC 28% (105%); diffusing capacity of lung for carbon monoxide 8.54 mmol · min^{-1} · kPa^{-1} (76%). Computed tomography showed a marked improvement (Fig 2).

Comment

Lung volume reduction surgery leads to improvement of exercise tolerance, lung function, and quality of life for selected patients by resecting nonfunctional emphysematous lung parenchyma [2]. Selection criteria for surgery were defined by the National Emphysema Treatment Trial and others [2–5]. Lung volume reduction surgery is deemed to be an elective procedure performed after pulmonary rehabilitation and is generally not advised for ventilator-dependent patients with respiratory failure. Hansson and colleagues [6] described the case of a patient who required invasive mechanical ventilation owing to acute respiratory failure, chronic obstructive pulmonary disease exacerbation, bilateral pneumothoraces, and massive air leak. The patient underwent emergency bilateral LVRS, including leak closure and pleurectomy through a median sternotomy. Pulmonary function tests improved and arterial blood gas normalized 3 months after surgery. In a more chronic setting, Criner and associates [7] reported 3 patients with recurrent chronic obstructive pulmonary disease exacerbations, respiratory failure, and long-term mechanical ventilation (from 11 to 16 weeks). The LVRS enabled weaning from mechanical ventilation for these patients.

We described the case of successful LVRS for a ventilated patient with acute respiratory failure and decompensated cor pulmonale on venovenoarterial ECLS. Despite the critical situation, it was thought that this young patient with minor comorbidities and complete preoperative workup for LVRS 18 months earlier would benefit from ECLS and LVRS. The ECLS in venovenoarterial mode unloaded the failing right ventricle while enabling sufficient oxygenation until the heart and lung recovered from aspiration pneumonia. The combination of medical treatment, including antibiotics as well as LVRS, enabled ECLS weaning.

Extracorporeal life support has not been reported in combination with LVRS, but its routine use as a bridge to lung transplantation allowed safe perioperative management [8]. Predictive factors of good functional results after LVRS included the slowly decreasing preoperative exercise tolerance, the upper lobe predominance of emphysema with compression of functional lung parenchyma at the base, the pulmonary hyperinflation

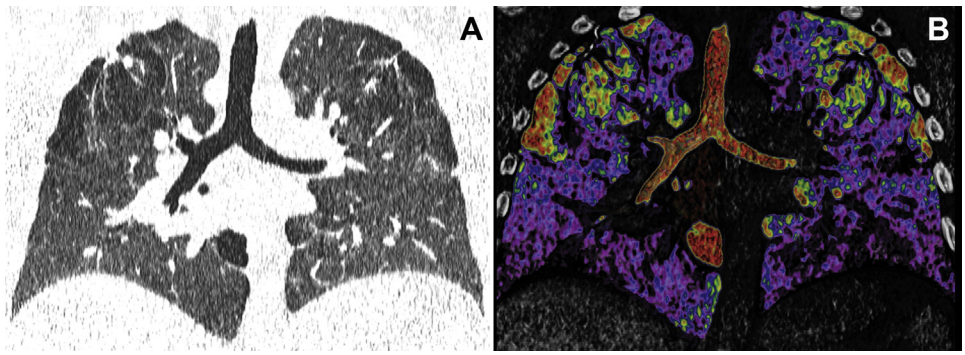

Fig 2. Chest computed tomography 4 months after lung volume reduction surgery in (A) lung window and (B) densitometry. Most of the emphysematous lung parenchyma was removed, and the diaphragms recovered their physiologic convexity.

(RV/TLC 63%), and the FEV_1 and diffusing capacity of lung for carbon monoxide that were greater than 20% of predicted.

In conclusion, LVRS was successfully performed in a highly selected patient with acute respiratory failure and decompensated cor pulmonale on ECLS.

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