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Our experience with VV ECMO-assisted surgery: case report series

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Veno-venous extracorporeal membrane oxygenation (VV ECMO) is a technique of extracorporeal support that facilitates blood gas exchange, enabling the complete replacement of lung function for a specified duration, such as during surgery. By using this method, we are able to provide surgical treatment to highly selected patients who would otherwise be unable to undergo thoracic surgery, including tracheal/carinal surgery and high-risk one-lung ventilation due to previous lung resection or severe lung impairment. This case series presents our experience with elective and acute ECMO-assisted thoracic surgery (excluding lung transplantation and cardiac surgery).

Key words: veno-venous extracorporeal membrane oxygenation, thoracic surgery, acute respiratory distress syndrome.

Naše zkušenosti s VV ECMO asistovanou chirurgií – série kazuistik

Veno-venózní extrakorporální membránová oxygenace (VV ECMO) je metoda mimotělní podpory zajišťující adekvátní okysličení a eliminaci oxidu uhličitého. Touto metodou jsme schopni poskytnout chirurgickou léčbu vysoce selektovaným pacientům, kteří by jinak nemohli podstoupit hrudní operaci (tracheální/karinální chirurgie, rizikové ventilace jedné plíce z důvodu předchozí resekce plic nebo těžkého postižení plic). Tato série kazuistik představuje naše zkušenosti s elektivní a akutní hrudní chirurgií asistovanou VV ECMO (kromě transplantace plic a kardiochirurgie).

Klíčová slova: VV ECMO, hrudní chirurgie, akutní respirační selhání.

Introduction

To facilitate access to vascular structures and bronchi, lung resection surgery is typically performed with selective intubation and ventilation on a collapsed (non-ventilated) lung. Acute respiratory distress syndrome (ARDS) is one example of a medical condition that can make one-lung ventilation difficult or impossible. Other examples include a previous pneumonectomy, a planned lobectomy in a patient who has already undergone a bilobectomy or lobectomy on the other side, and severe bullous emphysema of the lung that remains untreated. Also, selective intubation might not be possible for patients who have tracheal stenosis, tracheomalacia, injured tracheobronchial tree, or pressure on the tracheobronchial tree from the outside (mediastinum).

The thoracic surgeon must anticipate these non-standard situations and, if necessary, consider a possible alternative to ensure safe surgery with adequate ventilation. One option that may completely replace lung ventilation is veno-venous extracorporeal membrane oxygenation (VV ECMO). VV ECMO support facilitates blood gas exchange and can entirely replace lung function for a specified duration, such as during surgery [1]. Unlike cardiopulmonary bypass, VV ECMO can continue post-thoracic surgery for days or weeks. With its use, we are able to offer safe surgical treatment to highly selected patients in whom benefits outweigh the risks. Despite its potential benefits, the intraoperative use of VV ECMO in thoracic surgery remains rare, often reserved for transplant surgery departments [2].

In our cases, the indications for elective VV ECMO-assisted surgery included either impossible or high-risk selective intubation and/or one-lung ventilation in patients who were otherwise functionally capable of lung resection. Indications for acute VV ECMO-assisted surgery were surgical interventions in patients with respiratory failure (ARDS) including empyema, lung abscess, bronchopleural fistula, and massive air-leak and lung necrosis.

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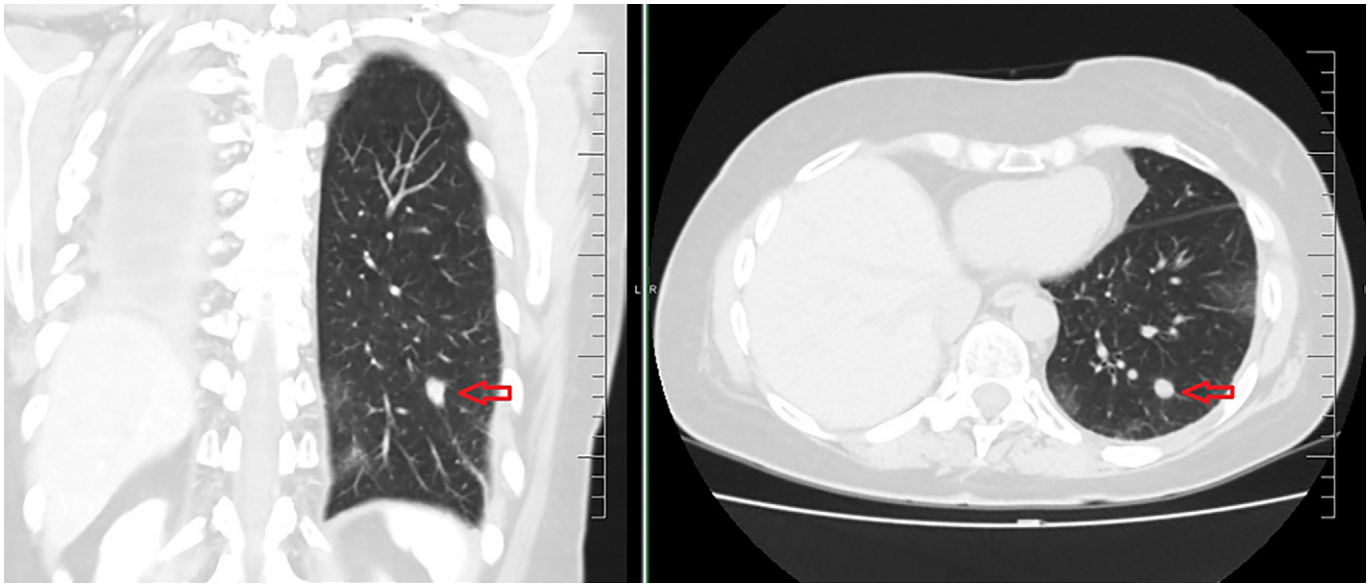
Fig. 1. *Metastases of malignant melanoma, labeled with an arrow*



Presentation of Cases

Between February 2019 and November 2024, fifteen VV ECMO-assisted thoracic surgeries were done at St. Anne's University Hospital in Brno. The patients included 5 women and 10 men with a mean age of 60 years. Seven patients underwent elective surgery, including five lung tumor resections and two cases of benign etiology. Eight patients were operated on urgently: one with a post-pneumonectomy bronchopleural fistula, another with a tracheal injury and massive air leak, two with empyema, two with pneumothorax (abscess rupture), one with an expanding bulla, and one with lung lobe necrosis.

In both elective and acute settings, the Cardiohelp ECMO system with HLS heparin coated sets by Maquet (Getinge Group) were used. Before the surgery in elective cases, we performed percutaneous cannulation under ultrasound guidance directly in the operating room. We performed cannulation in the intensive care unit in the same manner for acute cases. We inserted suction cannulae 23-25 F into the femoral vein and returned cannulae 19-21 F to the jugular vein. We always performed the priming of the ECMO circuit with saline, without adding any heparin. We administered only a bolus of heparin of 2000 j prior to the cannulation, leaving patients completely without anticoagulation peri- and postoperatively. We started ECMO in the same manner in acute cases, but in the intensive care unit.

In elective cases, airways were secured with orotracheal intubation and total intravenous anesthesia with propofol infusion was used. We monitored the depth of anesthesia using the bispectral index (BIS) and maintained it at BIS 40-60. During elective surgery, we completely disconnected patients from the ventilator once they reached 50 ml/kg of ECMO blood flow, enabling them to remain apneic throughout the entire procedure. In acute settings, 50 ml/kg of ECMO blood flow was usually not enough to maintain sufficient oxygenation (most of the patients were septic). Therefore, during the surgery, we selectively intubated these patients (Robertshaw endobronchial tube 37-41 Fr) and performed one-lung ventilation as well. Should the patients fail to wean off VV ECMO within 24 hours, our plan was to start anticoagulation with heparin at a target aPTTr of 1.5–2 fold, contingent on the occurrence of bleeding. However, we weaned all elective cases from ECMO within 24 hours after surgery.

The typical indication for elective VV ECMO-assisted surgery was lung resection in a patient after a previous resection (lobectomy or pneumonectomy) on the contralateral lung, where reduced pulmonary reserve makes one-lung ventilation unsafe. Most of the surgeries were performed due to lung tumors. Specifically, one right-sided and one left-sided lobectomy were done after a left/right-sided lobectomy, one right-sided wedge resection was done in a patient after left-sided lobectomy, and metastasectomy (malignant melanoma) was performed in a patient after pneumonectomy (Fig. 1). One patient with tracheomalacia had lobectomy and one with an intrathoracic goiter compressing the trachea, who was unable to undergo selective intubation, had left hemithyroidectomy. Finally, the last patient, who had a history of three pneumothoraxes and bullous emphysema, underwent bullectomy (Fig. 2).

Indications for acute VV ECMO-assisted surgery were mainly infections in the field of ARDS (one lung abscess in a patient with COVID-19 pneumonia, two lung necroses in a patient with severe community-acquired pneumonia, and two cases of empyema). The remaining cases included one expanding bulla causing respiratory failure necessitating prolonged artificial ventilation, one bronchopleural fistulation after right pneumonectomy (Fig. 3), and two patients with iatrogenic pneumomediastinum/pneumothorax (one post-intubation tracheal trauma, one pneumothorax after failed drainage). Table 1 summarizes the details for all cases.

There were no postoperative complications in elective VV ECMO-assisted surgery. Acute VV ECMO-assisted surgery was complicated in five patients (two with hemothorax, one with hemoperitoneum, one with infection in the groin at the site of cannula insertion, and one with hematoma in the area of the iliopsoas muscle after suction cannula malposition). Three of these complications (both cases of hemothorax and the hemoperitoneum) required acute surgical revision.

Tab. 1. *Patient characteristics*

No.	Sex	Age	Indication	Diagnosis	Co-morbidity	Procedure	No. of procedure	ECMO duration (days)	Postoperative complications	30-day mortality yes = 1	Hospital LOS
1	W	60	elective	Left lower lobe melanoma metastases	Post right pneumonectomy	Wedge resection, thoracotomy	1	1	no	0	7
2	W	66	elective	NSCLC left upper lobe	Tracheal malatia	Lobectomy, VATS	1	1	no	0	10
3	M	71	elective	MPLC right upper lobe	After left lower lobectomy	Lobectomy, right, open thoracotomy	1	1	no	0	10
4	M	78	elective	Emphysema bullosum, left sided pneumothorax	Impossible one-lung ventilation	LVRS (bullectomy), open thoracotomy	1	1	no	0	7
5	W	51	elective	MPLC left lobe	After right lower lobectomy	Lobectomy, open thoracotomy	1	1	no	0	5
6	M	78	elective	Intrathoracic goiter	Tracheal compression	Hemithyroidectomy, sternotomy	1	1	no	0	8
7	M	72	elective	MPLC right upper lobe	After left lower lobectomy	Wedge resection, open thoracotomy	1	1	no	0	5
8	M	75	acute	Broncho pleural fistulation	Post right pneumonectomy	Bronchial suture, omentoplasty, open thoracotomy	2	2	Musculus psoas hematoma	1	19
9	W	26	acute	Empyema gr. II	ARDS	Surgical treatment, VATS	3	18	Hemothorax	1	18
10	M	54	acute	Empyema gr.II	ARDS	Surgical treatment, open thoracotomy	1	1	no	0	38
11	M	49	acute	Expansive bulla	CHOPN, severe pulmonary hypertension	Wedge resection, open thoracotomy	1	1	no	0	63
12	W	60	acute	Pneumothorax, pneumomediastinum, tracheal injury	ARDS	Tracheal suture, Open thoracotomy	1	14	no	1	14
13	M	64	acute	Pneumothorax after failed drainage	ARDS	Wedge resection, open thoracotomy	1	3	Hemoperitoneum (patient after recent hemicolectomy)	0	21
14	M	60	acute	Pulmonary abscess, pneumothorax, empyema,	ARDS	Wedge resection, open thoracotomy	3	14	Infection at the cannulation site	0	100
15	M	33	acute	Lung necrosis right upper and left lower lobe	ARDS	2× Lobectomy, open thoracotomy	3	16	Hemothorax	0	90+ still counting

ARDS – acute respiratory distress syndrome; COPD – chronic obstructive pulmonary disease; LOS – length of stay; LVRS – lung volume reduction surgery; MPLC – multiple lung cancer; NSCLC – non small cell lung cancer; VATS – video assisted thoracoscopic surgery; VV ECMO – veno-venous extracorporeal membrane oxygenation.

Fig. 2. *Persistent pneumothorax in the field of panlobular emphysema*

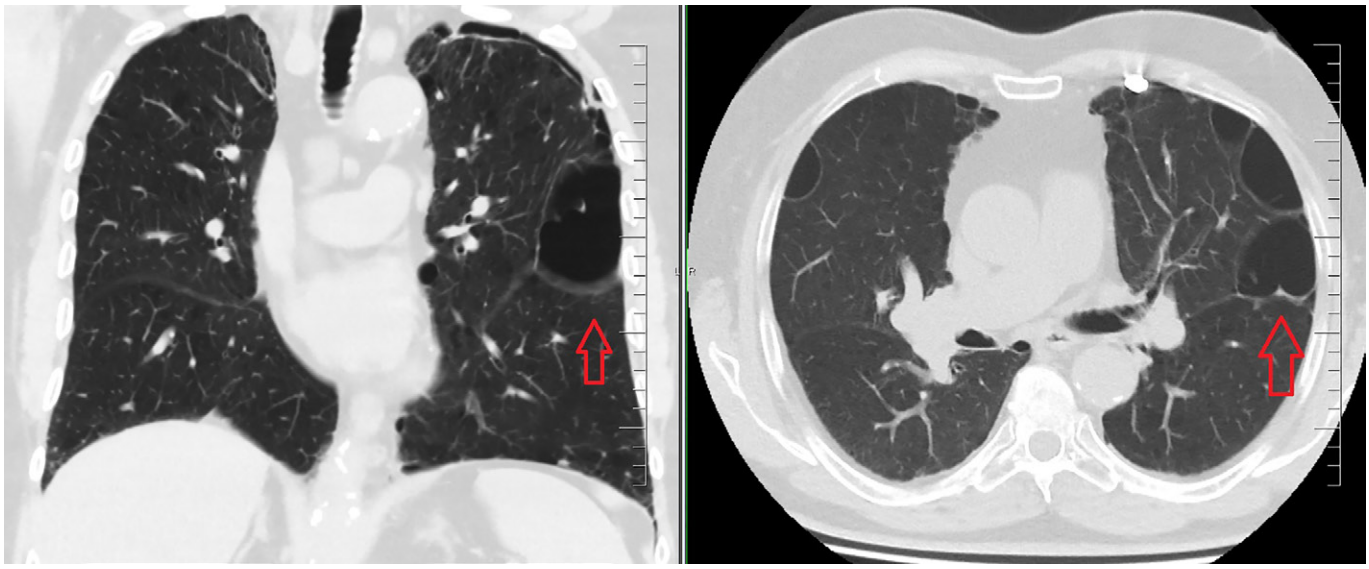
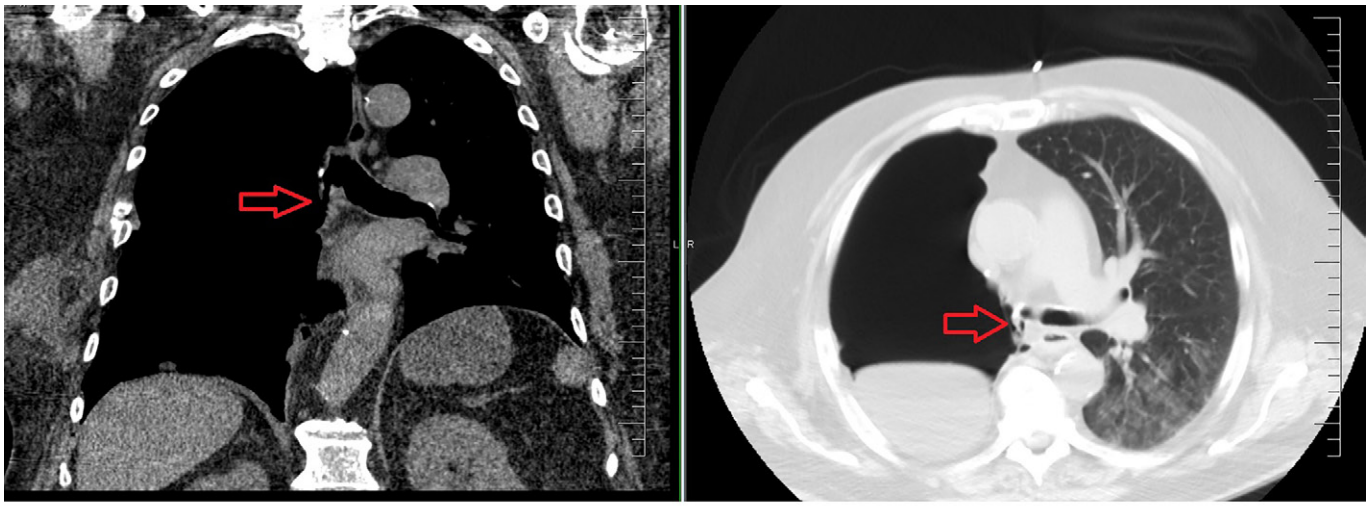


Fig. 3. *Bronchopleural fistulation after right-sided pneumonectomy*



In elective VV ECMO-assisted surgeries, the duration of ECMO was one day, whereas in acute VV ECMO-assisted surgeries, the median duration of ECMO was 9 (2-15) days. None of the patients died during surgery. In elective cases, the 30-day mortality was 0%. In acute cases, the 30-day mortality was 37.5% (all patients died of complications related to ARDS). The median of hospital length of stay was 7 (5-10) days and 30 (19-77) days in elective and in acute cases, respectively.

Discussion

The primary indication for VV ECMO-assisted surgery in our 15 patients was the difficulty or impossibility of one-lung ventilation due to lung impairment or previous lung resections. Impossible selective intubation was the reason in two cases only (tracheomalacia, external tracheal compression). The risk of complications and mortality during elective VV ECMO-assisted surgery was very low. This implies that a small group of patients who would not normally be able to undergo surgery due to their inability to tolerate one-lung ventilation or selective intubation could safely undergo lung resections. A significant mortality rate occurred in acute cases, and bleeding frequently complicated the postoperative course, partly due to the anticoagulation required for ECMO. However, the underlying disease caused the mortality, and all ECMO-associated complications resolved.

Jet ventilation, apneic ventilation with high-flow oxygen, or intubation through the surgical field into the distal trachea can provide oxygenation/ventilation in situations where selective intubation is impossible due to obstructions, tracheomalacia, or airway surgery [3]. Barotrauma can complicate jet ventilation, which limits its use in obese patients with COPD [3]. Endotracheal oxygenation, which involves high oxygen flow through a small probe, is an easy technique for oxygenation. However, without ventilation, it can cause hypercapnia, which can lead to hypercapnic acidosis. Furthermore, the duration of apnea, ideally limited to 30 minutes [4], frequently fails to provide adequate time for surgery. Periodical cross-field intubations may prolong surgery time and require frequent cooperation between the surgical and anesthesia teams.

Similar ventilation techniques, extended by intermittent conventional ventilation, can also be used for patients in whom airways could be secured, but one-lung ventilation is not possible or is associated with

a high risk of pulmonary injury. However, these techniques reduce surgical clarity and usually allow only rapid and relatively easy procedures (talc, biopsy, and wedge resection).

As an alternative to the above options, the use of cardiopulmonary bypass, extracorporeal CO_2 removal (ECCO2R), or ECMO (VV for lung resection only, VA for surgery involving both the heart and large vessels) can be considered. High doses of anticoagulation are required for cardiopulmonary bypass, and its use may not extend beyond the operating room. ECCO2R is good for carbon dioxide elimination, but oxygenation is poor, and therefore some combination with (ultraprotective) ventilation is necessary. ECMO, on the other hand, does not have these limitations, can be managed without anticoagulation, provides an excellent gas exchange, and its use can be extended for the postoperative period. We have exclusively used the VV ECMO in our cases.

The use of VV ECMO has been described in cases of tracheobronchial tree resection, carina resection, sleeve lobectomies [5–7], tracheobronchial tree injury [8, 9], and cases of large mediastinal tumors causing tracheal compression [10]. Moreover, VV ECMO has been used to support a wide range of procedures where reduced pulmonary reserve makes one-lung ventilation impossible or unsafe. Oey et al. [11] described the resection of an emphysematous bulla after a previous pneumonectomy. Tsunezuka et al. reported resection of bullae in the sense of lung volume reduction surgery (LVRS) in severe emphysema [12]. VV ECMO has also been used during lung resection surgery following previous resections, such as lobectomies and pneumonectomies on the contralateral lung [13].

Several authors have described the use of VV ECMO in ARDS patients who underwent limited lung resections for aspergillosis or lung abscess [14, 15], persistent massive air leak [16], or lung necrosis [17].

Conclusion

Patients in whom selective intubation and/or ventilation is not possible but who require surgery may benefit from VV ECMO. Morbidity and mortality rates in carefully selected patients for VV ECMO-assisted elective lung resection surgery are very low. Patients with respiratory failure requiring surgical treatment may also benefit from VV ECMO. In this case, morbidity and post-operative mortality are high, but related to the underlying disease.

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