

## Obesity-related respiratory failure: a new area for extracorporeal lung support?

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Obesity has become a worldwide health concern. The prevalence of obese adults in Switzerland has risen significantly over the last decade to 12% [1]. In the intensive care unit (ICU), obese patients are recognised as a specific population at higher risk of developing respiratory failure as obesity is characterised by pathophysiological changes in the mechanics of the respiratory system that tend to further enhance impairment of gas exchange [2]. Pulmonary compliance and functional residual capacity (FRC) are reduced by the negative effects of thoracic wall weight and abdominal fat mass, leading to decreased arterial oxygenation. Supine position, general anaesthesia and mechanical ventilation are known factors that exacerbate atelectasis, leading to worsening hypoxaemia and pulmonary infections. Oxygen consumption and the work of breathing are increased in this specific population of patients, leading to an increased production of carbon dioxide (CO<sub>2</sub>), especially when there is an associated obesity hypoventilation syndrome and a decreased respiratory drive [3]. The increased abdominal and visceral adipose tissue deposits lead to increased abdominal pressure. The diaphragm is passively pushed cranially, leading to a decreased capacity of the chest and to reduced respiratory system compliance [4]. Obese patients also have an increase in airway resistance, but not after normalisation by lung volume, as the major change remains the decreased FRC leading to atelectasis. Finally, as mentioned earlier, obesity is a major risk factor for obstructive apnoea syndrome, which also worsens hypercapnia and induces systemic hypertension [5]. In the ICU, the main challenges with obese patients are to take into account these pulmonary pathophysiological characteristics when choosing the best management options.

Now in *Swiss Medical Weekly*, Lederer et al. report the case of a 33-year-old morbidly obese (body mass index 84 kg/m<sup>2</sup>) female patient with severe hypercapnia (PaCO<sub>2</sub> 15.1 kPa) leading to severe respiratory acidosis (pH 6.96) in a context of sepsis [6]. Because noninvasive ventilation failed, the authors treated this refractory hypercapnia with venovenous extracorporeal membrane oxygenation (VV-ECMO) as an alternative to intubation and mechanical ventilation.

In cases of acute respiratory failure in obese patients, the first management step should be noninvasive ventilation in

order to avoid intubation. Indeed, obesity and obstructive apnoea syndrome, and a fortiori the combination of both, are risk factors for difficult intubation in these patients [7]. A higher level of positive end-expiratory pressure (PEEP) might be used to reduce hypercapnia [8]. However, in the event of noninvasive ventilation failure, other procedural strategies are mandatory. The potentially difficult airway management and intubation in obese patients systematically requires that a difficult airway management protocol should be applied to prevent complications related to the intubation procedure (severe desaturation and hypoxaemia, hypotension and cardiac arrest). In order to avoid both baro/volotrauma and atelecto/biotrauma after tracheal intubation, mechanical ventilation strategies should include the association of low tidal volume set according to ideal body weight (lung protective ventilation), moderate to high PEEP and recruitment manoeuvres [9]. However, if oro-tracheal intubation and mechanical ventilation may be not possible or are supposed to present a too high risk, VV-ECMO may be an option to avoid all these factual complications.

ECMO technology is rapidly improving, allowing treatment of patients with the most severe forms of respiratory failure [10]. Few years ago, VV-ECMO was recognised as a rescue therapy for refractory severe acute respiratory distress syndrome (ARDS) when mechanical ventilation was failing. In order to allow injured lung tissue to rest and heal, VV-ECMO needs to provide total respiratory support, achieving the function of blood oxygenation and CO<sub>2</sub> removal independently of the lungs [11]. In this situation, very large cannulas are mandatory to achieve high blood flows. Therefore, VV-ECMO is associated with a high risk of severe complications such as bleeding, thromboembolic events and infection [12]. The recent EOLIA trial results showed that severe ARDS patients randomised to the early ECMO arm had an 11% lower mortality than controls, although the difference did not reach statistical significance. Noticeably, 28% of controls who became very sick despite optimal maximal medical management, crossed over to rescue ECMO for refractory hypoxaemia [13]. Finally, the observed favourable trend seen despite the high crossover rate suggests that utilisation of immediate VV-ECMO in

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**Table 1:** Extracorporeal lung support techniques.

	Partial extracorporeal support (ECCO <sub>2</sub> R)			Total extracorporeal support (ECMO)	
	Very low flow	Low flow	Middle flow	High flow	High flow
Blood flow (ml/min)	200–400	400–500	600–1000	2500–5000	2500–7000
Vascular access	Venovenous	Venovenous	Venovenous	Venovenous	Venovenous
Catheter/cannula diameter	13 Fr	15.5 Fr	18–19 Fr	27–31 Fr	Drainage: 25–29 Fr
Catheter/cannula configuration	Single double-lumen	Single double-lumen	Single double-lumen	Single double-lumen	Reinjection: 17–21 Fr
Priming volume (ml)	140–160	200–300	250–350	300–500	300–500
Anti-Xa activity (UI/l)	0.3–0.4	0.3–0.4	0.3–0.4	0.2–0.3	0.2–0.3
Membrane surface (m <sup>2</sup> )	0.32	0.59	0.65	1.8	1.8
CO <sub>2</sub> extraction (% of baseline)	<25	25	50	>50	>50
O <sub>2</sub> transfer (ml/min)	0	10	20	150–300	150–350
Commercial devices	Baxter PrismaLung®	Alung Hemolung® Hemodec Decap®	Novalung MiniLung®	Maquet CardioHelp® Novalung XLung®	Maquet CardioHelp® Novalung XLung®

adequately trained centres might be a safe and effective option in patients with very severe ARDS.

Extracorporeal carbon dioxide removal (ECCO<sub>2</sub>R) is a lower blood flow VV-ECMO technique providing partial respiratory support by removal of CO<sub>2</sub> through an extracorporeal membrane with minimal or no impact on oxygenation [14, 15]. CO<sub>2</sub> removal is carried out by the application of high sweep fresh gas flow, generating a CO<sub>2</sub> diffusion gradient through the membrane. It first emerged as a potential respiratory support strategy to improve the respiratory management of patients with ARDS [16–20]. Advances in technology and a better knowledge of the technique have enabled its use in other clinical syndromes, such as decompensated chronic obstructive pulmonary disease (COPD), severe asthma, as a bridge to transplantation [21] and in morbidly obese patients [22]. The newer ECCO<sub>2</sub>R systems enable the use of smaller cannulas, such as single dual-lumen cannula or even haemofiltration catheters, in order to reduce complexity, expenses and side-effects. However, these systems allow blood flows between 300 and 1500 ml/min, depending of the design of the circuit, the size of the cannula and the area of the membrane. Characteristics of the different extracorporeal devices in terms of capability to oxygenate and CO<sub>2</sub> removal are presented in table 1. An animal study showed that a blood flow of 750 to 1000 ml/min was needed to achieve normal pH values, and that at lower blood flow rates, animals remained acidotic [23]. Even if very low blood flow devices are able to remove sufficient CO<sub>2</sub> in deeply sedated and paralysed ARDS patients with a low production of CO<sub>2</sub> [24], patients with increased CO<sub>2</sub> production may require systems with higher blood flow to significantly correct the respiratory acidosis and thus improve their clinical status. Even though ECCO<sub>2</sub>R appears to be effective in improving gas exchanges, in reducing hypercapnic acidosis and, possibly, in decreasing the rate of endotracheal intubation, its use can lead to adverse events and may have pulmonary and haemodynamic consequences. In a systematic review of the existing literature, ECCO<sub>2</sub>R-related complications were bleeding episodes related to anticoagulation with sometime severe haemorrhagic events, cannulation site(s) bleeding, haematoma, aneurism formation, haemolysis, heparin-induced thrombocytopenia and thrombosis, and some patients required intubation due to the resulting haemodynamic and/or respiratory instability [25]. Mechanical events are also described, such as a malfunctioning or failing pump, malfunctioning or failing oxygenator, malfunctioning or failing heat exchanger, clot for-

mation and air embolism [25]. Caution should be exercised in obese patients for whom cannulation is particularly challenging and should be accomplished by experienced physicians.

Finally, obese patients with respiratory decompensation requiring hospitalisation in the ICU require specific management, balancing the risks and benefits of the various existing strategies. Noninvasive ventilation is the first therapeutic step. However, if this fails, orotracheal intubation and conventional mechanical ventilation are now challenged by extracorporeal techniques. In cases with severe hypoxaemia, high-flow VV-ECMO is the technique for effectively correcting oxygenation, whereas in hypercapnic decompensation, the ECCO<sub>2</sub>R technique, with lower blood flow, allows CO<sub>2</sub> removal. Nevertheless, an attempt to eliminate CO<sub>2</sub> with insufficient blood flow risks being insufficiently effective in this type of patient, who produce a high quantity of CO<sub>2</sub>. Although these extracorporeal techniques are not, nowadays, studied enough to be recommended in place of conventional techniques, they are used successfully in many ICUs. Therefore, we can only advise intensivists to use the techniques for which they have most experience to treat their patients.

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