User Report

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Use of Respiratory Dialysis to Enable Lung Protective Ventilation in a Patient with Moderate ARDS due to Crush Syndrome from a Mining Accident: A case report

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This report describes the case of a 41 year old male copper mine worker who developed moderate acute respiratory distress syndrome (ARDS) after being crushed and buried by falling stones in a mine accident. The patient became septic and difficult to ventilate in the days following amputation of his severely crushed left leg. He was transferred from a regional hospital to Wroclaw University Hospital in Wroclaw, Poland for ECMO consideration. However, the primary difficulty in providing respiratory support was not oxygenation but rather carbon dioxide (CO_2) removal. Instead of ECMO, the patient was treated with low-flow respiratory dialysis using the Hemolung Respiratory Assist System (RAS). With flows of 400-500 mL/min through a single, 15.5 French venous cannula, the Hemolung was successfully utilized to enable significant reduction of the high peak inspiratory pressures needed to normalize the patients pH and carbon dioxide tension and prevent ventilator-induced lung injury.

Case Description

The patient suffered multiple traumatic injuries in the mining accident, including a severely crushed left leg. Following transport to a nearby regional hospital, the patient was immediately intubated and brought to the operating room for amputation of his left leg. He was diagnosed with crush syndrome, having fractures of his ribs, right scapula, and thoracic vertebra, and required noradrenaline infusion for cardiovascular support. There were no injuries to his head or abdominal region. Over the course of several days, the patient became septic due to infection of the leg wound, and was increasingly difficult to ventilate. Increasing concentrations of oxygen were required and moderate ARDS developed, however, the primary difficulty with providing mechanical ventilation was with CO_2 elimination. A computerized tomography (CT) scan of the thorax was performed, but no significant abnormalities were found. The patient also required continuous renal hemodiafiltration due to anuria from the crush injury. On the eighth day, a re-amputation was required and on return from the operating arena, the patient experienced a short cardiac arrest. Following resuscitation, it was determined that the patient required more than just mechanical ventilatory support.

The patient was transported that day to our ICU at the Wroclaw University Hospital for extracorporeal membrane oxygenation (ECMO) therapy. Upon arrival, initial assessment revealed a Glasgow Coma Score (GCS) of 3, an arterial pH of 7.0, an arterial CO_2 tension ($PaCO_2$) of 63.8 mmHg, and an arterial oxygen tension (PaO_2) of 171.9 mmHg on 100% oxygen. His amputation wound remained open for management of the infection. The patient experienced three additional episodes of short cardiac arrests just prior to transport, upon admission to our hospital, and in our ICU. He was found to have high potassium levels over 8 mmoles/L.

Continuous veno-venous hemodiafiltration (CVVHD) was quickly reinstituted through the left jugular catheter that had been inserted at the regional hospital, and at the same time, very aggressive mechanical ventilation was implemented with high inspiratory pressures to achieve elimination of as much CO_2 as possible. His blood gases improved to a pH of 7.29, a $PaCO_2$ of 43.8 mmHg, and an oxygen fraction of 70%, but with dangerously high inspiratory pressures of 46-50 cmH_2O. Although he was transported to us for ECMO therapy, the Hemolung RAS was also available in our unit, which provided us with the option to utilize low-flow extracorporeal CO_2 removal through a much smaller cannula than what is needed for ECMO. This patient was a good candidate for use of the Hemolung RAS because our primary challenge in providing pulmonary support was with CO_2 removal, not oxygenation.

Hemolung therapy was initiated after the patient had been in our ICU for 5 hours. The Hemolung 15.5 Fr catheter was inserted without complication in the right jugular vein. The patient was already cannulated in the left jugular vein for renal replacement therapy, and had an arterial line in his right femoral artery. Although the Hemolung can also be applied with a femoral catheter, this was not ideal in this case due to the severe left leg injury. Despite these limitations, both Hemolung and renal replacement therapy were successfully implemented without complication.

The Hemolung RAS provided very effective treatment, allowing a rapid decrease in the inspiratory pressures to 25 cmH_2O while simultaneously improving acidosis. This was a large difference in ventilation. Within four hours of starting Hemolung therapy, the blood gases had improved to a pH of 7.37, a $PaCO_2$ of 43.0 mmHg, and a PaO_2 of 90.3 mmHg on 65% oxygen. Because of the cardiac arrests, we maintained a low positive end expiratory pressure (PEEP) so as not to disturb cerebral circulation, and for this same reason, needed to eliminate hypercapnia. With Hemolung therapy, normocapnia was restored and consistently maintained at low inspiratory pressures over the course of the next 7 days while the patient improved and recovered from his injuries and the infection. Ventilatory measures, blood gases, and Hemolung operational parameters during the course of Hemolung therapy are shown in **Table 1** and graphed in **Figure 1**.

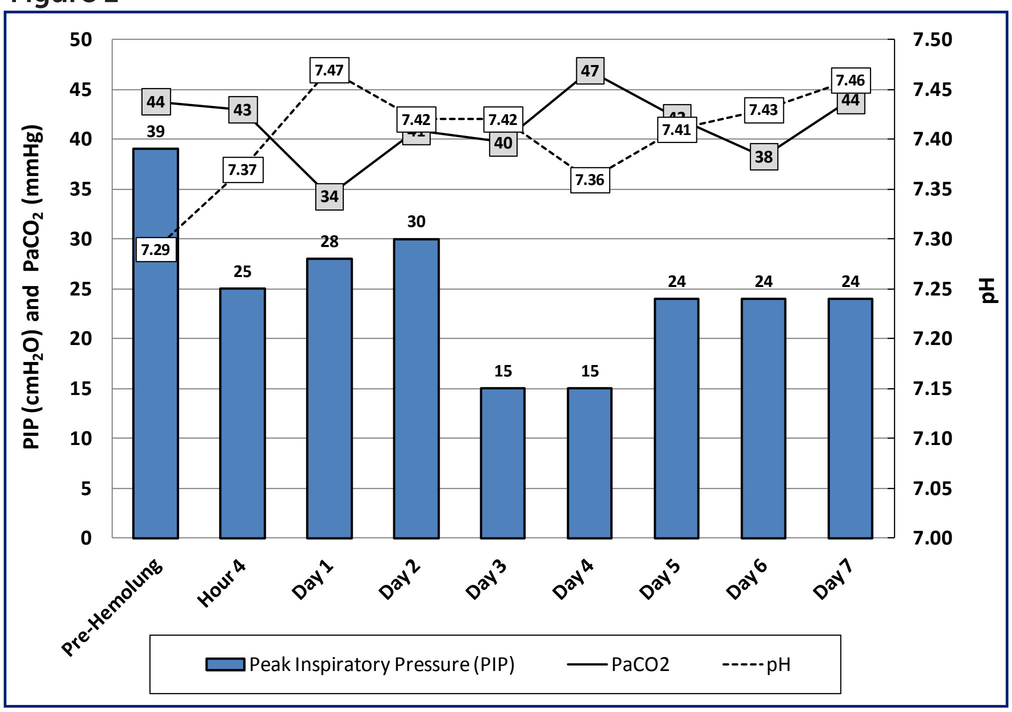
On the sixth day, we turned down the sweep gas of the Hemolung to reduce the rate of CO_2 removal, and the patient remained stable. Over the course of the next day, the Hemolung was then weaned and the catheter removed. After removal of the Hemolung, the patient was able to be supported using bi-level ventilation with a PEEP of 5 cm H_2O and pressure support ventilation (PSV) at 16 cm H_2O on 35% O_2. One week later, a tracheotomy was performed and after another week, the injured leg was re-amputated and the wound closed. Weaning of ventilator was started and the patient was able to breathe spontaneously for up to 4 hours at the end of his stay in our ICU while his general status continued to improve. The patient was ultimately discharged from our ICU three weeks after Hemolung therapy, and transported back to the original regional hospital for rehabilitation therapy. Respiratory dialysis was not only straightforward to implement and manage, but it achieved our goal of significantly reducing peak inspiratory pressures to protect the lungs and maintain normocapnia.

Table 1 Ventilation, Blood Gas and Hemolung Measures During Therapy

	Pre-Hemolung	Hour 4	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Ventilation Parameters									
Ventilator Mode	PCV	PCV-VG	PCV-VG	PCV-VG	Bi-Level	Bi-Level	Bi-Level	Bi-Level	PCV-VG
Respiratory Rate	28	22	28	28	21	14	16	22	22
Tidal Volume (mL)	830	618	600	565	757	850	780	818	625
Minute Ventilation (L/min)	23.2	13.6	16.8	15.8	15.9	11.9	12.5	18.0	13.7
Peak Inspiratory Pressure (cmH_2O)	39	25	28	30	15	15	24	24	24
PEEP (cmH_2O)	3	5	6	6	5	5	6	6	6
Inspired Oxygen Fraction	70	65	45	45	40	40	45	45	40
Arterial Blood Gases									
Oxygen tension (mmHg)	91.4	90.3	99.5	103.8	75.8	76.1	91.5	89.2	118.8
Oxygen Saturation (%)	95.8	96.7	97.9	97.9	95.5	95.1	95.4	97.1	98.8
pH	7.29	7.37	7.47	7.42	7.42	7.36	7.41	7.43	7.46
Carbon Dioxide Tension (mmHg)	43.8	43.0	34.3	40.9	39.7	46.9	42.2	38.3	44.0
Bicarbonate (mmole/L)	20.8	24.8	24.6	26.1	25.5	26.1	26.1	25.0	30.7
Hemolung Operational Parameters									
Blood Flow (mL/min)	-	530	590	530	420	370	390	400	410
Motor Speed (RPM)	-	1399	1401	1300	1101	1100	1100	1100	1100
Sweep Gas Flow (L/min)	-	10	10	10	10	10	10	10	1
Carbon Dioxide Removal (mL/min)	-	83	65	61	64	69	59	56	30

PCV – pressure control ventilation, PCV-VG – pressure control ventilation-volume guaranteed, RPM – revolutions per minute.

Figure 1



Discussion with Dr. Smiechowicz

Q: Describe why you decided to use the Hemolung instead of ECMO?

A: ECMO is more difficult because it requires insertion of large cannulae. Furthermore, the patient didn't need ECMO because his oxygenation was sufficient. He had a moderate degree of ARDS with a ratio of PaO_2 to FiO_2 that was never below 140. He had renal failure with metabolic acidosis exaggerated by respiratory acidosis. His potassium level was high because of this acidosis, which was likely related to at least one of his cardiac arrests. When he arrived at our ICU, he had poor neurologic condition, with a GCS of 3. This improved to 11 at the time we transferred him back to his local hospital.

Q: With the Hemolung system, did you still require an extra nurse as with ECMO?

A: For ECMO patients, we use a dedicated nurse and perfusionist. In cases with the Hemolung, we were able to operate it with only a dedicated nurse, as it runs quite like continuous renal replacement therapy (CRRT). CRRT is a standard procedure in our ICU and nurses are very familiar with it; this is very easy for them. They had no problems with the Hemolung because it was similar to managing CRRT.

Q: Did anything eventful happen during the course of the 7 day therapy with respect to the Hemolung?

A: This is a very great advantage of Hemolung treatment, that it runs very smoothly. It does not absorb personnel time very much, not like with ECMO. The patient did not experience any complications during the course of Hemolung therapy. He required several units of blood in our ICU, however this was associated with his amputation, which was kept open to manage the infection.

Q: Were there any difficulties inserting the Hemolung catheter?

A: The insertion procedure was performed by percutaneously inserting a guidewire and then successively dilating the entry site without cutting the skin, followed by placement of the catheter. Although dilation in this manner was not as easy, it was very effective in preventing any bleeding at the cannulation site, despite systemic anticoagulation with heparin.

About the Author

Dr. Smiechowicz is a physician at the Wrocław Medical University Hospital in Wrocław, Poland. He received no compensation in association with this case report and has no conflicts of interest to disclose. Dr. Smiechowicz can be reached via email at ksmiech@yahoo.com.

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