We are unaware of any reported pediatric cases of combining differential lung ventilation and extracorporeal membrane oxygenation (ECMO) support for successful management of BP fistula.

A 16-year-old male patient was found unresponsive at the scene of a vehicular accident. His injuries included lung contusion with prominent pneumatoceles, which evolved into a BP fistula with persistent left-lung air leak within 24 hours of admission, and a small frontal subarachnoid hemorrhage, punctate intracranial hemorrhages, and skeletal bone fractures (C6 through T1 spinous processes, multiple ribs, and scapular).

The initial management included mechanical ventilator support, multiple chest tube placements, and bronchoscopy that ruled out disruption of the bronchial tree. On hospital day 4, the left chest tube was connected with suction because of the increasing size of pneumothorax. Gas exchange remained stable, with PaO₂'s in the range of 60 mm Hg. Subsequently, oxygenation worsened despite a trial of inhaled nitric oxide. The conventional endotracheal tube was advanced into the right main stem bronchus without clinical improvement. On hospital day 5, placement of a 26 Fr left-lumen Bronchopart endotracheal tube (Rusch, Kemen, Germany) allowed for selective occlusion of the left bronchus and single-lung ventilation of the right lung, resulting in improvement in oxygenation and in mixed venous saturation. The left lung remained collapsed, with small residual apical pneumothorax but no active air leak.

The patient continued to have stable hemodynamics and perfusion until hospital day 19, when he gradually experienced significantly worsening hypoxemia (PaO₂ 32 mm Hg and FiO₂ of 1.0) and hypercarbia (PaCO₂ 104–134 mm Hg). After the endotracheal tube was repositioned, the airway was suctioned, sedation was increased, and neuromuscular blockade accomplished, there was a transient resolution followed by progressively worsening hypoxemia (oxygen saturation of 40–45%) and hypercarbia (PaCO₂ greater than 100 mm Hg) and requirement for high-frequency oscillator ventilation. Repeated inflation of the left lung resulted in a left-sided tension pneumothorax and hypotension, requiring bolus-dose epinephrine and multiple volume boluses. Despite immediate placement of the chest tubes on suction to evacuate the pneumothorax and resumption of isolation and deflation of his left lung, the patient continued to have worsening oxygenation, which necessitated emergent use of venovenous extracorporeal membrane oxygenation (ECMO) with a bicaval dual lumen catheter (Avalon Elite, Maquet, Rastatt, Germany) through the right internal jugular vein. Ventilator strategy while the patient was receiving ECMO consisted of selective right lung ventilation and rest-ventilator settings on the right lung in pressure-regulated volume control with a tidal volume of 170 mL, rate 10, PEEP 15 cm H₂O, FiO₂ 0.5, and iNO 20 ppm.

Repeated bronchoscopy on hospital day 23 indicated small areas of bronchial mucosal ischemia where the bronchial cuff of the double-lumen endotracheal tube was positioned, without evidence of bronchial tear. On
hospital day 24, a second ventilator was used to provide continuous positive airway pressure of 5 cm water to gently reexpand the atelectatic left lung. Over the next several days, PEEP was slowly increased to the left lung, with gradual improvement in lung compliance and concomitant improvement in chest roentgenograms. The small residual pneumothoraces continued to remain stable in size, with increasing left lung aeration, and on hospital day 31, the double-lumen endotracheal tube was exchanged for a conventional endotracheal tube and conventional ventilation was well tolerated.

The patient was successfully weaned from ECMO and decannulated on hospital day 32 after 19 days of support. On hospital day 41, after several days of improvement in respiratory status and weaning from PEEP, tracheostomy and gastrostomy tubes were placed. He was discharged from the pediatric intensive care unit on hospital day 55, remained in the rehabilitation service for the next few weeks, and was discharged uneventfully on hospital day 73.

Comment

Our experience is the first reported pediatric case wherein differential lung ventilation strategy and ECMO support were used for managing persistent BP fistula. Previous reports indicated successful differential lung ventilation in adults with BP fistula either intraoperatively [3, 4] or postoperatively [4]. Differential lung ventilation has also been used successfully in patients with unilateral lung disease wherein lung compliance in the two lungs necessitates vastly different ventilation strategies for the two lungs. Among children, differential lung ventilation has predominantly been used in smaller patients in the operating room for video-assisted thoracoscopic surgery where lung deflation optimizes the surgical field reducing retractor-induced injury of lung tissue [5]. The use of differential lung ventilation is limited in children because it requires at least a 26F double-lumen tube (Rusch, Kernen, Germany) that may only be used for children older than 8 years. Alternatively, a Univent tube (Fuji, Tokyo, Japan) is available with a 3.5-mm internal diameter that may be used in children older than 6 years [6]. Pawar and Marraro [6] have related some experience with a new device, the Marrow double-lumen tube with the potential for perioperative use in the infant age range. In our case, although single-lung occlusion and ventilation stabilized an air leak, improving oxygenation and ventilation, it ultimately failed because ventilation from a single, also injured, lung could not sustain our patient long enough for complete resolution of the contralateral injury.

In adults, some case reports indicate successful uses of ECMO, extracorporeal lung assist devices, or both for the treatment of persistent BP fistulas, mostly in the postoperative period after surgical resection [2, 7, 8], but to our knowledge no reported pediatric cases have included the simultaneous use of differential lung ventilation and ECMO for managing BP fistula. In clinical scenarios where survival rates are extremely low [1], we show that ECMO can successfully be used in children when conventional strategies used to treat BP fistula fail. Differential lung ventilation while a patient is receiving ECMO also allows the healthy lung to be ventilated while concomitantly allowing the diseased lung to collapse completely and heal the BP fistula. This strategy prevents or mitigates atelectasis while also gradually reinflating the diseased or injured lung, thus protecting against extreme and rapid pressures, with the potential to rupture a healing fistula.

We demonstrate that a combination of differential lung ventilation and judicious use of ECMO has an important role for rescue therapy when conventional treatment of BP fistula has failed. Further, this strategy can be used in the pediatric age range, subject to size limitation.

References


Successful Management of Cold-Induced Urticaria During Hypothermic Circulatory Arrest

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Cold-induced urticaria (CIU) is a potentially life-threatening immunologic disorder characterized by swelling and edema of exposed tissue in response to cold.

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