Neonatal Paracorporeal Lung Assist Device for Respiratory Failure

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Neonates who experience respiratory failure despite maximal ventilatory support have only extracorporeal membrane oxygenation as a rescue therapy, but it has very poor outcomes as a bridge to transplantation. A pumpless lung-assist device has been used in adults as a bridge to lung transplantation. An alternative membrane oxygenator, the Quadrox iD, is a suitable size for neonatal blood flow. Here we report the use of the Quadrox iD membrane oxygenator with central cannulation as a paracorporeal respiratory support therapy for a neonate with alveolar capillary dysplasia awaiting lung transplantation.

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FEATURE ARTICLES

Neonates with primary respiratory failure in whom ventilator support fails require a long-term extracorporeal lung assist device as a bridge to transplant.

A full-term infant whose older sibling had died because of alveolar capillary dysplasia (ACD) required intubation and inotropic support on day of life (DOL) 2. He was given a presumed diagnosis of ACD and listed for lung transplantation. He required escalation of cardiopulmonary support and was given venoarterial (VA) extracorporeal membrane oxygenation (ECMO) on DOL 18. Given the poor clinical outcomes of lung transplantations from ECMO in the pediatric population [1], we decided to transition our patient to paracorporeal pulmonary artery (PA) to left atrium (LA) oxygenator support using the Quadrox iD (Maquet, Wayne, NJ), which is the membrane oxygenator for our pediatric ECMO circuit. We reviewed the case with the university human research protection office and discussed the risks and benefits of the device with this patient's parents, who agreed to proceed. The paracorporeal PA to LA lung assist device (LAD) provides adequate oxygenation and ventilation if the majority of the cardiac output is shunted through the device. With his pulmonary hypertension demonstrated by ECHO, we expected that to be the case. We based that assumption on our successful experience supporting a 2-year-old child with primary pulmonary hypertension with the sLA Novalung (Novalung GmbH, Heilbronn, Germany) that was placed in a PA–LA configuration [2]. The Quadrox iD has a minimum flow of 200 mL/min compared with 500 mL/min for the Novalung, making it suitable for a neonate.

The transition from ECMO to the LAD was performed on DOL 23. The patient was cannulated through the chest and transitioned to traditional cardiopulmonary bypass. To create the shunt, a 6-mm Berlin Heart atrial cannula (Berlin Heart AG, Berlin, Germany) was sewn to the PA with a short interposed 8-mm GoreTex shunt. A 16F DLP right-angle single-stage venous cannula (DLP Medtronic, Inc, Grand Rapids, MI) was placed in the left atrium through the intra-atrial groove with pursestring securement. Adequate shunt flow through the oxygenator was achieved and allowed prompt weaning from cardiopulmonary bypass support. A Sechrist 3500 low-flow air–oxygen mixer (Sechrist Industries, Inc, Anaheim, CA) was used to control gas flow and inspired oxygen fraction. Flow through the Quadrox oxygenator was continuously monitored with a Transonic HT110 bypass flowmeter (Transonic Systems, Inc, Ithaca, NY). Continuous pre-oxygenator and postoxygenator pressure monitoring was performed. An open lung biopsy confirmed the diagnosis of ACD.

The transmembrane flow rates were initially 250 mL/min, increasing to 450 mL/min over the first 5 days (Fig 1). The transmembrane pressure gradient served as a marker of buildup of thrombus in the oxygenator and was 6 to 7 mm Hg at baseline (Fig 2). Other than milrinone, which was maintained to support the right ventricle, inotropic support was weaned by postoperative day (POD) 4, and extubation was performed on POD 15 (Fig 3). Anticoagulation was achieved with a continuous heparin infusion with a goal activated clotting time (ACT) of 180 to 220 seconds. Antithrombin III (ATIII) activity levels were monitored, and ATIII was replaced (Thrombate III, Grifols USA, Los Angeles, CA) to maintain levels above 80%. Aspirin (20.25 mg/day) was used for additional anticoagulation effect. The circuit was monitored for thrombus buildup. The oxygenator was changed at the bedside on POD 14, and a connector was changed on POD 21, both because of thrombus

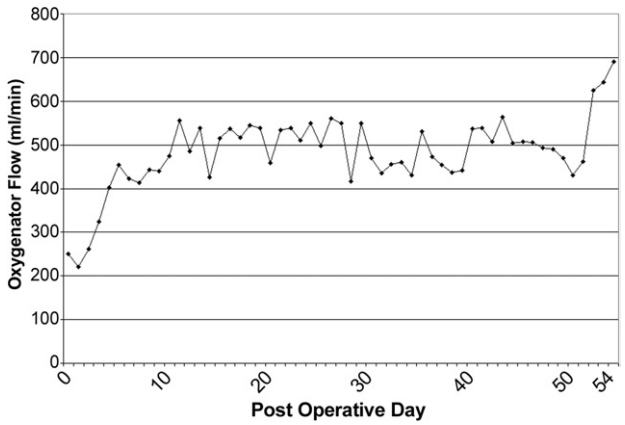

Fig 1. Flow through oxygenator recorded hourly with ultrasound flow meter.

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formation. LAD support was complicated by hemodynamically significant atrial ectopic tachycardia, attributed to local LA cannula effect, but was controlled with amiodarone and digoxin. The major complication during support was bilateral extraaxial hemorrhages diagnosed by computed tomography of the head after a generalized seizure on POD 43. The intracranial hemorrhages progressed over the next 10 days in spite of minimization of anticoagulation and required removal of the patient from the lung transplantation list and redirection of care to comfort care. The patient died on POD 54.

Comment

Owing to poor outcomes [1], children who require VA ECMO are not eligible for lung transplantation in our institution. The iLA Novalung has been used as a bridge to lung transplantation in adult patients [2, 3]. Our team was the first to support a small child with primary pulmonary hypertension with the iLA Novalung in a PA–LA configuration [2]. During support we were able to extubate the child and reverse remodel his pulmonary vasculature to the point where paracorporeal pulmonary support was no longer needed. This led us to apply a similar support system in a small infant with ACD using the Quadrox iD membrane. Our patient was supported for 54 days while awaiting a suitable organ donor. One central issue was the suitable timing for extubation and whether atelectasis would lead to pneumonia. After extubation, respiratory drive was minimal, leading to shallow breathing and episodes of apnea; however, the patient did not experience respiratory infection. For anticoagulation, we followed our typical ECMO heparin therapy with

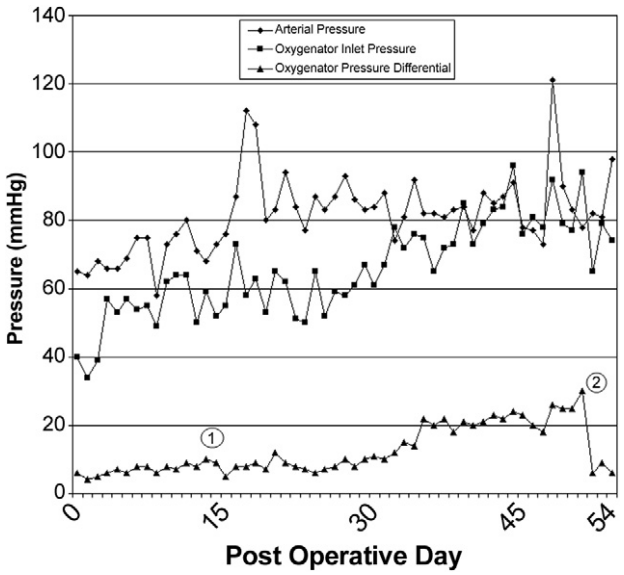

Fig 2. Measurements of arterial pressure, inlet oxygenator pressure, and pressure differential across oxygenator over the course of device support. The two oxygenator changes are marked by circled numbers adjacent to the pressure differential values.

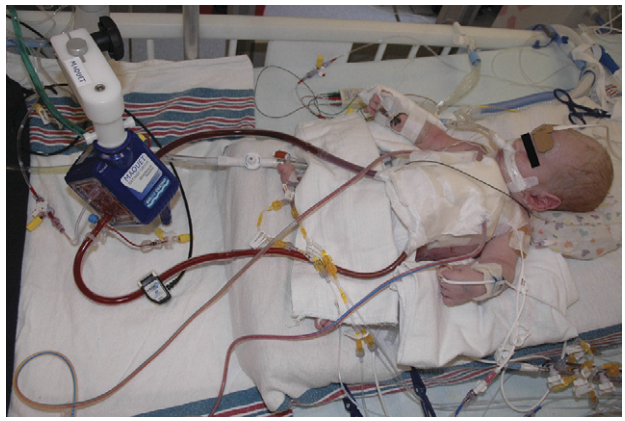

Fig 3. Patient in intensive care unit bed supported with paracorporeal lung assist device before extubation.

ACT goals of 180 to 220 seconds. Additionally, we used low-dose aspirin and the repletion of ATII to >80%. Aspirin has been described as an adjunct to anticoagulation with the Novalung in adults [4]. Adult patients who are treated with the Novalung typically receive anticoagulation therapy with heparin, with a goal ACT of 160 to 180 [2] or 160 to 200 seconds [3]. Based on our experience, the decreased risk of intracranial bleeding by maintaining ACT levels in the range of 160 to 180 seconds outweighs the possibility of increased oxygenator or circuit changes. We used an ATIII infusion to maintain higher ATIII levels and to ensure the effectiveness of heparin. It remains to be seen whether this approach is beneficial and cost effective.

Cannulation strategy remains an unresolved challenge in these small patients. The use of the right-angled Berlin Heart cannula for the pulmonary artery with the short GoreTex graft extension worked well. On autopsy, the LA had a significant amount of thrombus, including clot surrounding and occluding the cannula. A low-resistance LA cannula without a metal protrusion into the LA cavity is essential to minimize thrombus formation. Certainly, the intracranial bleeds in this patient may have been hemorrhagic conversions of embolic strokes from an intracardiac source. A LA cannulation strategy that incorporates a reinforced graft sewn near the intraatrial groove may be an improved approach.

In summary, our experience suggests that long-term support of neonates and infants awaiting lung transplantation with the paracorporeal LAD is feasible. Optimization of cannulation strategy and anticoagulation management will be the focus of future clinical efforts as the breath of clinical application of this therapy is explored.

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Customized Transapical Thoracic Endovascular Repair for Acute Type A Dissection

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FEATURE ARTICLES

A 67-year-old patient with severe comorbidities and acute type A aortic dissection with pericardial tamponade was treated with an endograft introduced through a mini-thoracotomy and puncture of the left ventricular apex. Final angiography showed complete coverage of the dissection. Early and 6-month follow-up computed tomography showed full apposition of the endograft without residual dissection. Transapical thoracic endovascular repair of acute type A aortic dissection appears to be feasible and is associated with minimal physiologic compromise. It may provide a less invasive alternative for patients with increased operative mortality.

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Operative mortality from acute aortic type A dissection has decreased in recent years owing to major advancements in ascending aortic surgery, but it is still substantial in patients who are older, have severe comorbidities, and have had previous cardiac surgery [1–3]. Thoracic endovascular aortic repair (TEVAR) has been developed as a therapeutic alternative to open repair of the descending thoracic aorta during the last decade [4]. MacDonald and colleagues [5] recently described the transapical access for TEVAR using a mini-thoracotomy. Other groups have adopted this technique and reported their experience [6, 7]. Potential advantages of transapical access include avoidance of downstream access problems, short distance, nearly unlimited profile, and instant decompression of the pericardial tamponade. We describe the technique of transapical TEVAR in a case of acute type A aortic dissection of the ascending aorta with pericardial tamponade.

A 67-year-old man with a known history of chronic obstructive pulmonary disease (Global Initiative for Chronic Obstructive Lung Disease class IV), heart failure (New York Heart Association III), and chronic renal failure (stage III) was admitted with acute chest pain and dyspnea resulting from an acute dissection of the ascending aorta (Stanford type A, De Bakey type II). Computed tomographic angiography revealed an entry tear at the minor curve of the ascending aorta with dissection stretching from the left coronary ostium to the innominate artery (IA; Fig 1). Pericardial hemorrhage was present with 12-mm thickness on axial imaging.

Dr Kölbel discloses that he has a financial relationship with Cook Medical.

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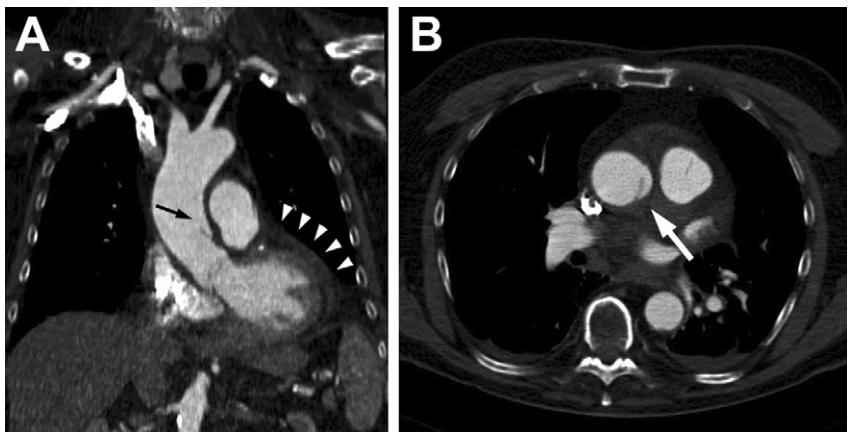

Fig 1. Preoperative computed tomography angiography. (A) Multiplanar reconstruction depicting the dissection at the minor curve of the ascending aorta (black arrow) and pericardial hemorrhage (white arrowheads). (B) Axial image showing normal aortic diameter at the level of dissection (white arrow).

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