

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, Kemen, 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.

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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

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a cold stimulus. We describe the successful management of a patient with a history of severe CIU who required coronary bypass and repair of an ascending aortic aneurysm using 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 a cold stimulus. Severe cases are associated with hypotension and cardiovascular collapse. We describe the successful management of a 70-year-old man with a previous history of CIU who required coronary bypass and repair of an ascending aortic aneurysm using hypothermic circulatory arrest.

An 81-kg, 70-year-old man presented with symptoms of crescendo angina. Coronary angiography revealed a 90% left main coronary artery lesion and an 80% lesion in a dominant right coronary artery. Thoracic computed tomography revealed an ascending aortic aneurysm measuring 56 mm in maximal diameter, tapering to 40 mm at the takeoff of the innominate artery and 35 mm in the arch. The aortic root was not enlarged. Echocardiography revealed preserved left ventricular function with a normally functioning aortic valve. In addition to a history of hypertension and a history of previous smoking, the patient had cold-induced urticaria (CIU) with earlier life-threatening reactions to cold, having had an anaphylactic reaction secondary to river water emersion.

Circulatory arrest was deemed essential to perform an adequate repair of his ascending aortic aneurysm. Allergy and clinical immunology colleagues were consulted, and the patient was prescribed a 3-day treatment schedule of cetirizine 10 mg orally twice daily (BID) and ranitidine 150 mg orally BID. This degree of histamine receptor antagonism produced a partial suppression of his ice test result. The ice test involves applying a frozen solid 1-cm glass vial (containing a diluent negative control for standard skin testing) to the volar surface of the patient's forearm and observing for the development of a wheal and flare response. At 7 days preoperatively, this regimen was expanded to cetirizine 20 mg BID, ranitidine 150 mg BID, and montelukast 10 mg once daily. This was further expanded 5 days preoperatively to include prednisone 25 mg BID, which was continued until the day of operation. The patient's metoprolol was replaced with amlodipine. We used an extensive perioperative and intraoperative regimen consisting of combinations of methylprednisolone, ranitidine, and diphenhydramine. An hour before the patient was transferred to the operating room, he was given intravenous methylprednisolone 2 g, ranitidine 50 mg, and diphenhydramine 100 mg. Intravenous methylprednisolone 125 mg and diphenhydramine 100 mg

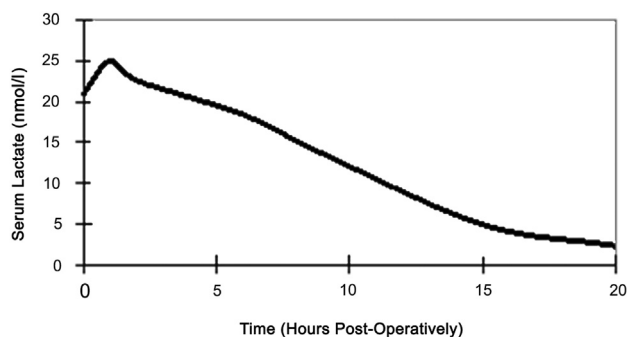
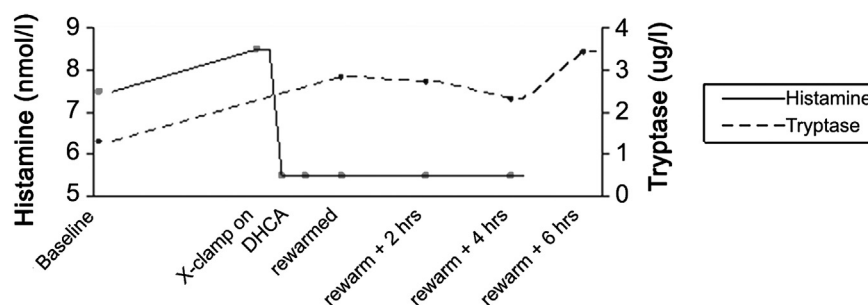


Fig 1. Postoperative serum lactate levels.

were given 1 hour before starting cardiopulmonary bypass. Before rewarming, we administered intravenous methylprednisolone 60 mg, ranitidine 50 mg, and diphenhydramine 100 mg. The patient also received methylprednisolone 60 mg, ranitidine 50 mg, and diphenhydramine 50 mg intravenously 6 hours postoperatively. Intraoperatively and postoperatively we sampled serial serum tryptase and plasma histamine levels. Arterial cannulation was accomplished through the right axillary artery with an 8-mm Dacron graft. We used a 2-stage right atrial venous cannula. Cardioplegia was delivered using initial antegrade doses through the root with subsequent retrograde administration through the coronary sinus. Intraoperatively, the patient was cooled to a core temperature of 28°C. Distal bypass grafting was performed while the patient was cooling. At 28°C, circulatory arrest was commenced using selective antegrade cerebral perfusion (delivered at 28°C) through the right axillary artery. Total circulatory arrest time was 11 minutes. Total cardiopulmonary bypass time was 159 minutes with 78 minutes of cross-clamping. The patient proved difficult to rewarm, requiring more than an hour to attain normothermia. Systemic hypotension, managed with inotropic and pressor support, was an issue throughout the rewarming period. Once warm, the patient required only a low-dose epinephrine infusion. He experienced a brief but impressive lactic acidosis postoperatively (Fig 1). Pressor support was weaned several hours after the operation, and the acidosis resolved by the following morning. Serum histamine and tryptase levels were determined at baseline, at the onset of bypass, once the patient was cooled to 28°C, after completion of circulatory arrest, once rewarming was completed, and at 2, 4, and 6 hours after rewarming. Baseline serum histamine levels measured 7 nmol/L and tryptase levels were 1.3 µg/L. Serum histamine levels peaked at 8 nmol/L measured at the onset of bypass and remained at 5 nmol/L and less for all subsequent measurements. Serum tryptase levels ranged from 2.3 to 3.4 µg/L, with peak levels occurring 6 hours after rewarming (Fig 2). The patient recovered uneventfully and was discharged home on postoperative day 6.

Fig 2. Preoperative, intraoperative, and postoperative serum histamine and tryptase levels. (DHCA = deep hypothermic circulatory arrest; X-clamp = cross-clamp.)



Comment

CIU is an uncommon albeit well-described phenomenon resulting from mast cell degranulation with subsequent release of inflammatory mediators after cold exposure. Histamine appears to mediate most of the clinical manifestations. Its release is greatest on withdrawal of the cold stimulus. Avoidance of short-term and prolonged exposures to cold stimuli is central to the management of these individuals.

Although patients with CIU requiring cardiac operations have been reported [1–4], this remains an unusual clinical entity for cardiac surgeons. Booth and Parissis [1] reported on a patient with known CIU requiring coronary artery bypass grafting (CABG). They administered a combination of hydrocortisone, ranitidine, and chlorphenamine immediately before induction of anesthesia. This patient was kept normothermic throughout the case. Bakay and Onan [2] reported a similar patient with CIU who underwent CABG; they maintained the patient at or near 37°C. They administered 1 mg/kg methylprednisolone 12 hours preoperatively, with another 1 mg/kg methylprednisolone and a single dose of an antihistamine (pheniramine maleate, 45 mg) given intravenously before induction. Postoperatively the patient was given a 3-day tapering regimen of intravenous methylprednisolone. Johnston and colleagues [3] reported a patient with known CIU who required a coronary operation. He was administered diazepam, scopolamine, morphine, and hydrocortisone before entering the operating room; he also received intravenous administration of cimetidine (300 mg), diphenhydramine (90 mg), and hydrocortisone (100 mg) before induction of anesthesia. This patient was cooled to 31°C. Before rewarming, he was given 300 mg cimetidine and 90 mg diphenhydramine. Intraoperatively they observed a significant rise in serum histamine levels; however, the patient remained clinically stable. Lancey and associates [4] reported a case of combined aortic valve replacement and CABG in a patient with CIU. This patient was cooled to 32°C for the procedure. An extensive regimen of fexofenadine, ranitidine, methylprednisolone, and diphenhydramine was used beginning 5 days preoperatively and continuing into the postoperative course.

To our knowledge, this is the first reported case of a patient with CIU undergoing hypothermic circulatory arrest. Similar to Lancey and colleagues, we used an

extensive preoperative, intraoperative, and postoperative regimen to blunt the CIU response. Antegrade cerebral perfusion throughout the period of circulatory arrest allowed us to cool the patient to no lower than 28°C.

Others have shown an increase in plasma histamine levels with rewarming during cardiopulmonary bypass [3]. To blunt this response we used an extensive pharmacologic regimen initiated well in advance of the operative date. The lack of an observed rise in tryptase levels suggests that we successfully achieved mast cell stabilization. Our patient required transient low-level inotropic support for a few hours postoperatively. He also experienced significant lactic acidosis, with serum lactate levels peaking at 25 mmol/L 2 hours postoperatively. There was no clinical evidence of organ malperfusion or ischemia, and he remained clinically stable. Although the cause of the lactic acidosis remains unclear, we believe it to be due to “washout” from peripheral tissue beds. Although not known to be characteristic of CIU, perhaps this patient had a pronounced peripheral arterial vasoconstriction in response to cold stimuli. If this patient had effectively reduced flow to peripheral tissue beds during cooling, this would explain the accumulation of lactic acid and the subsequent spike we observed after reperfusion. This could also help explain the time it took and the difficulty we had rewarming the patient.

In conclusion, this case suggests that patients with CIU complicated by anaphylaxis can successfully undergo cardiac bypass operations using deep hypothermic circulatory arrest. We would recommend using an aggressive preoperative, intraoperative, and postoperative pharmacologic strategy.

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