Case Report

Successful Use of Cardiopulmonary Bypass and Ultrafiltration for Metabolic Resuscitation of a Moribund Child With Acute Perianesthetic Rhabdomyolysis: A Case Report of Unsuspected Malignant Hyperthermia

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ABSTRACT

Life-threatening malignant hyperthermia and/or related disorders can rapidly strike the genetically susceptible individual when exposed to certain anesthetic agents, producing an acute syndrome in which death is likely unless immediate treatment is provided. This case report describes the use of cardiopulmonary bypass and ultrafiltration to resuscitate a moribund 10-year-old female who developed cardiac arrest from rhabdomyolytic hyperkalemia while receiving a general anesthetic for elective tonsillectomy. Subsequent muscle biopsy indicated the patient was susceptible to malignant hyperthermia.

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INTRODUCTION

Malignant hyperthermia (MH) is a genetic disorder of skeletal muscle characterized by hypermetabolic crises when exposed to certain anesthetic agents (1). Rhabdomyolysis, a potentially serious condition frequently seen in MH susceptibility, occurs from injury to the sarcolemma of skeletal muscle, with leakage of its components into the blood and urine (2). Perianesthetic MH and/or rhabdomyolysis seem to be most commonly triggered by the inhalant anesthetics halothane, enflurane, isoflurane, and the muscle relaxant succinylcholine (3, 4, 5).

Clinically, rhabdomyolysis is identified by increased levels of myoglobin, creatine kinase (CK), and potassium in the serum. High levels of myoglobin in the urine impart a reddish-brown color, which is frequently the first clinical indication of muscle damage (2). Acute rhabdomyolysis of skeletal muscle can occur in the absence of MH or other identifiable changes in metabolism (6, 7). MH is generally thought of in its most severe form, manifesting uncontrollable hyperthermia, hyperkalemia, and cardiac dysrhythmias. However, the clinical picture becomes obscured by the fact that MH can be highly variable and present with some or all of the many symptoms of the disorder (8)

When family history is either unknown or incomplete, it is inevitable that MH-susceptible patients will be anesthetized with triggering agents. When recognized early, the resultant crises can usually be managed by immediate cessation of all inhalation anesthetics and/or muscle relaxants, assisted ventilation with 100% oxygen, provision of symptomatic relief of early and late complications, and the administration of the drug dantrolene, which prevents the release of calcium into skeletal muscle myoplasm, helping to avert the crisis precipitated by continuous muscle contractions (9, 10).

Unfortunately, despite prompt recognition, the acute MH crisis can be refractory to conventional therapy and rapidly progress to massive physiological collapse. This case report describes such a scenario and the use of cardiopulmonary bypass (CPB) and ultrafiltration to reverse successfully the catastrophic metabolic crisis precipitated by massive rhabdomyolytic hyperkalemia in a patient with unsuspected MH.

CASE DESCRIPTION

A 10-year-old, 45 kg female had been previously healthy except for several episodes of streptococcal pharyngitis, recurrent tonsillitis, and a recent episode of peritonsillar cellulitis that resulted in moderate airway obstruction. The patient was referred for elective tonsillectomy at a local community hospital.

On the day of surgery, the patient underwent induction of general anesthesia for her tonsillectomy and was given propofol and fentanyl at 11:20 AM. Inhalant therapy consisted of forane, nitrous oxide, and oxygen. Upon attempting intubation, it was noted that the vocal chords were inadequately relaxed. Succinylcholine, 40 mg, was administered at 11:25 AM to facilitate intubation. Following intubation, the surgeon had difficulty opening the patient's jaw because of masseter spasm. The patient's color was noted to be poor, and a wide-complex bradyarrhythmia developed. Atropine was given, but the patient progressed to asystole. A code was called and cardiopulmonary resuscitation (CPR) began at 11:30 AM.

The initial resuscitative efforts consisted of sodium bicarbonate, epinephrine, lidocaine, and defibrillation without response. A cardiologist became involved as the resuscitative efforts continued. After 20 min of CPR, the initial electrolyte analysis showed a potassium of 10.2 meq/L. Insulin, dextrose, and rectal Kayexalate[a] were then given. Over the next hour, this regimen reduced the potassium to 8.5 meq/L, but the rhythm remained in asystole or ventricular fibrillation. Malignant hyperthermia was suspected and dantrolene and decadron were given. The patient developed several brief runs of ventricular tachycardia with high dose epinephrine during which she opened her eyes and moved her hands. Subsequent electrolyte analysis showed potassium levels once again approaching 10 meq/L.

After 60 min of resuscitation without significant response, the decision was made to transport the patient by helicopter, with ongoing CPR, to a nearby medical center where CPB could be established in order to support organ perfusion while attempting to normalize the hyperkalemia and other metabolic abnormalities. During transport, the patient had copious amounts of pink froth in the endotracheal tube, and her pupils were dilated and minimally reactive.

CASE MANAGEMENT

The extracorporeal circuit included an integrated pediatric membrane oxygenator,[b] 3/8-in arterial line, 3/8-in venous line, an arterial line filter,[c] a hemoconcentrator,[c] and a centrifugal pump.[d] The priming solution consisted of 1200 mL Lactated Ringers, 3000 IU heparin, 50 meq sodium bicarbonate, and 12.5 g mannitol.

The patient arrived in the operating room with ongoing CPR. When the chest was opened with a midline sternotomy, the heart was found to be distended and not contracting. The patient was heparinized, and open chest massage was performed while the aorta and right atrium were cannulated. The patient was then placed on CPB.

Initial blood gas analysis on CPB showed a pH of 6.89, pCO2 of 79 mmHG, PO2 of 141 mmHg, base deficit of −20 mmol/L, bicarbonate concentration of 14.2 mmol/L, and a se-

a Sanofi Winthrop Pharmaceuticals, New York, NY 10016
b Cobe VPCML, Cobe Laboratories, Arvada, CO 80004
c Bentley Division, Baxter Healthcare Corp., Irvine, CA 92713
d Medtronic Biomedicus, Eden Prairie, MN 55344

rum potassium of 10.3 meq/L. The patient was not febrile at any time before CPB, and the patient was kept normothermic. Flows ranged from 65 mL/kg/min to 80 mL/kg/min with venous saturations remaining above 60% throughout CPB. Ultrafiltration was immediately started, replacing the ultrafiltrate with 0.9% sodium chloride. A total of 12 liters of ultrafiltrate was removed during the course of CPB. Acidosis was corrected with the administration of sodium bicarbonate and THAM (tromethamine).

The objective was to support the circulation while normalizing the patient's electrolyte concentrations and acid-base status. Clinically, the large doses of sodium bicarbonate and fluid replacement with 0.9% sodium chloride tended to raise the serum sodium level, but the ongoing ultrafiltration was able to keep it within normal range. The ultrafiltration also reduced the patient's free calcium level, which was supplemented with calcium chloride administration. After 45 minutes of ultrafiltration and concurrent fluid replacement with 0.9% sodium chloride, the serum potassium was reduced to 5.8 meq/L and the anion gap normalized to 9 mmol/L. At this point, the patient went into a 2:1 block and then converted to normal sinus rhythm. CPB was continued an additional 101 min in an effort to correct persistent acidosis and to allow the heart to recover. Dark red urine was noted in the Foley catheter. Of concern during CPB was that the patient had evidence of ongoing acidosis and hyperkalemia, suggesting persistence of the previously suspected MH crisis, which was being treated during CPB with dantrolene.

When the patient became more stable, and the metabolic picture normalized, the patient was separated from CPB without difficulty on 5 mcg/kg/minute of dopamine and in normal sinus rhythm. The total time on CPB was 146 min and the total CPR time was 150 min.

POSTOPERATIVE COURSE

The patient had evidence of neurological function long into the code, but deteriorated and had minimally responsive and dilated pupils for almost 1 hour before CPB. However, the patient became responsive to questions shortly after coming off CPB, and subsequently returned to baseline cognitive function with no central nervous system deficits observed.

The pulmonary edema resolved after the cardiac rhythm was restored and the patient was extubated on postoperative day 2. The patient remained in sinus rhythm and maintained adequate, but labile blood pressure on dopamine.

The dark red urine observed during CPB was later determined to be myoglobinuria, with no red blood cells seen on microscopy. Hemodialysis was initiated immediately in the postoperative period in order to treat ongoing hyperkalemia and acidosis, and in expectation of total renal failure from myoglobin toxicity, which began several hours after CPB. After 2 days, the patient was switched to continuous arterial–venous hemodialysis with excellent control of electrolytes, acidosis, and fluid balance. Twice weekly outpatient hemodialysis was required for nearly 2 months before normal renal function returned.

The extent of rhabdomyolysis became clear when the CK level peaked at 671,744 U/L on the first postoperative day and compartment syndrome developed in both legs, especially in the quadriceps. Multiple fasciotomies were performed on postoperative day 1, releasing muscle bundles that were clearly under pressure. All muscle groups had viable tissue except the right calf. The patient initially had paralysis of both legs, which slowly improved during several months of physical therapy.

The patient developed disseminated intravascular coagulopathy shortly after resuscitation with CPB, which was treated with blood component therapy. During the patient's hospital course, she received 27 units of packed red blood cells, 30 units of platelets, 21 units of fresh frozen plasma, and 34 units of cryoprecipitate.

The patient had moderate abdominal distension, thought to be due to transient ischemia, that resolved on postoperative day 3. Subsequent feedings were tolerated well. The patient was discharged from the hospital after 38 days.

DISCUSSION

Rhabdomyolysis may be an underestimated entity that occurs as a primary disease or as a complication of MH susceptibility. The Malignant Hyperthermia Association of the United States suggests that one person in 200 may be at risk, with a mortality rate as high as 20% in those individuals who actually develop the syndrome (10). Those patients surviving a MH crisis frequently develop brain damage, renal failure, paralysis, and other major organ impairments. Because of its rapid onset, MH can create a life-threatening situation in minutes unless the condition is promptly recognized and treated (10).

The typical patient at risk for MH is young, muscular, usually male, and caucasian (10). The patient's history may include reports of intolerance to anesthetics, localized muscular weakness or cramps, joint hypermobility, orthopedic abnormalities such as spinal curvatures, or a disease such as Duchenne's muscular dystrophy (7, 9, 10). In addition to its recognition for MH susceptibility, Duchenne's muscular dystrophy has also been known to increase a patient's cardiac risk from general anesthesia because of difficult-to-resuscitate cardiac arrest, muscular rigidity, and acute rhabdomyolysis of skeletal muscles (7).

Jardon describes the inherited defect in the muscle cell as the beginning of the MH crisis (4). In normal muscle, intracellular calcium levels increase during contraction and decrease during relaxation. In MH, however, excessive intracellular calcium results in constant muscle contraction with the resultant increase in oxygen consumption and lactic acid production. Aerobic and anaerobic metabolism progress, resulting in meta-

bolic and respiratory acidosis and hypoxia. The high rate of muscle metabolism causes increases in carbon dioxide, lactic acid, and heat, all of which contribute to severe acid-base derangements and the rise in temperature encountered in classical MH (11).

Typically, tachycardia is the first sign of impending MH, followed by dysrhythmias, full body rigidity, hypotension, decreased cardiac output, and eventual heart failure and/or cardiac arrest (12). The accelerating acidosis increases membrane permeability and rhabdomyolysis, which causes increased levels of serum calcium, potassium, CK, and myoglobin. Elevated temperature, which may or may not be present, is considered a late sign of MH, as are electrolyte abnormalities, myoglobinuria, coagulopathy, and acute pulmonary edema (9). In this case, the clinical factors consistent with MH were a reaction to succinylcholine, hyperkalemic cardiac arrest, masseter spasm, myoglobinuria and renal failure, elevated CK, respiratory and metabolic acidosis, pulmonary edema, hypoxia, and coagulopathy. Of interest was the complete absence of hyperthermia and full body rigidity and the extremely rapid onset of cardiac arrest (5 min) following administration of succinylcholine.

Upon careful questioning of the family, it was discovered that the patient had frequent complaints of intermittent cramping of the chest muscles and had episodes of unexplained fevers throughout her childhood. In addition, several of the patient's siblings had frequent complaints of muscle cramping with exercise. Unknown to the family at the time of surgery, an uncle and his two children had all experienced severe reactions to anesthetics, with subsequent muscle biopsies testing positive for MH susceptibility. In addition, further investigation of the family history revealed several relatives with muscular dystrophy or related syndromes. With this knowledge, a muscle biopsy was recommended and performed on this patient, which tested positive for MH susceptibility.

Other than a slight limp attributable to weakness in one leg, the patient has made a complete recovery and leads a normal life. The patient continues to struggle with tonsillitis and has, with support from her family, emphatically refused to pursue another attempt at tonsillectomy.

Although the perfusion management of this case, in and of itself, was not unusual, the use of CPB and ultrafiltration for life-threatening acute rhabdomyolysis is rare, and to the best of our knowledge, has not been reported in the literature. However, the literature is replete with reports of acute rhabdomyolysis associated with halothane-succinylcholine anesthetic regimens in children, many of whom died because of the inability to support the circulation while correcting the underlying metabolic derangements.

This case clearly emphasizes that MH susceptibility may be revealed as isolated and extremely severe rhabdomyolysis, and that CPB and ultrafiltration can be integral to a patient's survival of this potentially life-threatening syndrome. The favorable outcome of this case is a reminder that, as the scope of practice and technology in perfusion continues to evolve, so does the pathogenesis and complexity of diseases requiring CPB and the skills of the cardiac surgical team.

REFERENCES

1. Yarborough J. Malignant hyperthermia. J Am Assoc Nurse Anesth. 1984;52:58–64.
2. Knochel JP. Mechanism of rhabdomyolysis. Curr Opin Rheumatol. 1993;5:725–31.
3. Felice-Johnson J, Sudds T, Bernet G. Malignant hyperthermia.: Current perspectives. Am J Hosp. Pharm. 1981; 38:646–51.
4. Jardon OM. Heat stroke, stress, and malignant hyperthermia. Nebr Med J. 1985;70:195–9.
5. Ryan JF, Kagen LJ, Hyman AI. Myoglobinemia after a single dose of succinylcholine. N Engl J Med 1971;285: 824–7.
6. Sethna NF, and Rockoff MA. Cardiac arrest following inhalation induction of anaesthesia in a child with Duchenne's muscular dystrophy. Can Anaesth Soc J. 1986;33: 799–802.
7. Resenberg H, and Heiman-Patterson T. Duchenne's muscular dystrophy and malignant hyperthermia: Another warning. Anesthesiology. 1983;59:362.
8. Braude BM, Press P, Moyes DG, et al. Unexpected hyperthermia manifestation during anesthesia. Anesthesiology. 1986;64:647–50.
9. Rogers AL, and Sturgeon CL. Malignant hyperthermia: A perioperative emergency. AORN J. 1985;41:369–74.
10. Thomas SD.Malignant hyperthermia. Crit Care Nurse. 1989;9:58–69.
11. Britt BA. Malignant hyperthermia. Can Anaesth Soc J. 1985;32:540–1.
12. Stehling L, and Brown D. Malignant hyperthermia: More than a rising temperature. Diagn Med. 1984;6:59–64.