A patient with McArdle disease underwent bowel surgery with general anesthesia and was successfully managed. McArdle disease is a rare skeletal muscle disorder affecting approximately 1 in 100,000 people. McArdle disease, also known as type V glycogen storage disease, is an autosomal recessive inherited condition caused by a missing or nonfunctioning enzyme called myophosphorylase C. This phosphorylase is the enzyme responsible for making glucose for energy. Individuals suffering from McArdle disease have muscles that cannot properly metabolize energy and may experience fatigue and failure during strenuous activities. When a patient with McArdle disease presents for any surgical procedure, a variety of anesthesia implications should be discussed and incorporated into the overall management of his or her care. Careful attention to adequate fluid management, appropriate neuromuscular blockade choices, normothermia maintenance, normoglycemia maintenance, blood pressure monitoring, and maintaining malignant hyperthermia precautions is critical to providing safe anesthesia to this unique patient population.

Keywords: McArdle disease, myophosphorylase C, rhabdomyolysis, thermoregulation, type V glycogen storage disease.

Case Summary
An ASA physical status 3, 48-year-old, 168-cm, 73-kg woman presented to the preoperative area for exploratory laparotomy secondary to rectal cancer. Symptom onset began 1 month prior to the patient’s scheduled surgery and included minimal rectal bleeding. The patient’s medical history included McArdle disease. She reported muscle cramping with exertion that affected her activity level on a daily basis. She was currently participating in a daily aerobic exercise regimen prescribed by her primary physician, which consisted of stretching and walking. The patient verbalized no difficulty urinating and said that her current urine color was clear and yellow. Her last reported incidence of myoglobinuria was approximately 2 years ago following a long bike ride. Surgical history consisted of 3 prior rectal surgeries for tumor resection. Anesthesia history was notable for a “slow wake-up” following her last 2 bowel resections, attributed to muscle weakness. The patient recalled requiring mechanical ventilation for a few hours after one case until she was extubated safely. The patient denied any drug and food allergies. The patient reported consuming 2 alcoholic beverages each day and denied smoking or illicit drug use. The patient also suffered from anxiety. Alprazolam was the only medication taken by this patient. The patient had not taken alprazolam on the day of her surgery.

Preoperative examination revealed an awake and cooperative patient with vital signs within normal limits. Airway assessment revealed a Mallampati II airway without major indicators for difficult intubation. Results of laboratory evaluations completed preoperatively were within normal physiologic parameters.
Current recommendations of the Malignant Hyperthermia Association of the United States (MHAUS) were followed to adequately prepare the room for potential crises. A 500-mL normal saline bolus and 4.0 mg of midazolam was administered via 18-gauge peripheral intravenous (IV) access prior to the patient entering the operating room. A higher dose of midazolam was chosen because the patient’s long-term benzodiazepine and alcohol use suggested probable tolerance formation.

The patient entered the operating room, where she was moved from the transport cart to the operating room table with staff assistance. After ASA standard monitors were placed, intravenous induction occurred using 100 µg of fentanyl, 150 mg of propofol, and 12.0 mg of cisatracurium, with atraumatic endotracheal tube placement. A radial arterial line and second IV line were started.

Figure. Images Illustrate How Muscles Run Out of Energy in McArdle Disease

Abbreviation: ATP, adenosine triphosphate.
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When anesthesia providers encounter a rare disorder such as McArdle disease, a systematic approach to gathering reliable resources, identifying important anesthesia considerations, and developing a safe and timely plan of action should occur. Reviewing the most recent information via anesthesia texts, the Online Mendelian Inheritance in Man website, contacting MHAUS, and reviewing the literature using a medical search engine are excellent suggestions for developing a safe anesthetic plan. For an elective case, adequate preparation for anesthesia of the patient with McArdle disease is paramount to prevent complications (Table 1). To prepare for a possible emergency, providers should assess the patient for MHS risk, develop an anesthetic strategy with a backup plan, and discuss these plans with the family and surgeon.

Following MHS protocols when preparing for the patient with McArdle disease is of controversy in current literature because of the rarity of McArdle disease and its underlying genetic heterogeneity, absolute certainty with regard to MHS may never be established. Lobato et al documented the theory of patients with McArdle disease being protected against MHS because their skeletal muscle cannot undergo prolonged spastic contracture. Benca and Hogan discussed the option of performing inhaled induction followed by nontriggering agent maintenance because of the weak association in patients with rare enzyme defects and malignant hyperthermia (Table 2). Although no clinical association between McArdle disease and malignant hyperthermia has been established, many of these patients have positive caffeine halothane contracture tests (CHCT). The CHCT thresholds distinguishing MHS from MHS-negative have historically been determined in the absence of other recognized muscle disease. These data suggest that contracture test results may have decreased specificity, sensitivity, and predictive value in patients with other coexisting neuromuscular diseases and enzymopathies such as McArdle disease.

If current MHAUS recommendations for patients at risk of malignant hyperthermia are to be followed, it is important to remember the 2009 changes in anesthesia machine preparation. First, the expired gas analyzer will indicate presence of residual volatile agent in the anesthesia circuit that must be flushed out. Also, if all the recommendations are completed, changing the CO₂ absorbent is no longer required. Finally, it is important that anesthesia providers are familiar with specific machine recommendations, because newer anesthesia workstations (eg, the Draeger Fabius, Draeger Medical, Telford, Pennsylvania) may require up to 60 minutes of preparation.

Patients with McArdle disease present with an increased susceptibility to rhabdomyolysis when energy demands escalate. The exact cause of rhabdomyolysis has not been identified in the literature to date but may be related to eccentric force being placed on “cramped”
muscles. Rhabdomyolysis can cause leakage of potentially toxic substances such as the iron-rich protein myoglobin and the electrolyte potassium into systemic circulation. Myoglobinuria may occur within a few hours of muscle injury and should be treated immediately to prevent acute tubular necrosis and obstructive nephropathy. Dark, cola-colored urine is the hallmark symptom of myoglobinuria. Rapidly developing rhabdomyolysis can cause a sudden increase in serum potassium levels and lead to cardiac arrhythmias.

To overcome rhabdomyolysis in the current case, the anesthesia providers assisted patient movement during all transports to decrease patient workload. Also, current literature recommends avoiding surgical and IV tourniquets when possible. Another method to avoid muscle injury, used in this case scenario, involves utilizing arterial blood pressure monitoring as opposed to noninvasive blood pressure cuff monitoring. Throughout the case, cisatracurium was administered, because this neuromuscular blocker did not cause fasciculations, which could have promoted skeletal muscle catabolism. Also, cisatracurium is primarily metabolized by Hoffman elimination via plasma esterases, which decreased renal demands and potential pathological insult. Finally, blanket warmers, fluid warmers, and IV meperidine are recommended for use throughout the perioperative period as prophylactic measures to prevent shivering and release of myoglobin into the bloodstream. In this case, the anesthesia providers had easy access to all 3 measures, which successfully prohibited large decreases in the patient’s temperature.

The perioperative administration of adequate intravenous dextrose solution is a common recommendation when managing care for patients with McArdle disease. These fluids are used as they have shown extended muscle exercise tolerance in experimental studies of patients with limited reserve. Because dextrose decreases the risk of anaerobic glycolysis in patients with McArdle disease, a postoperative infusion is usually recommended until the patient is able to take in complex carbohydrates by mouth. If the surgery is minor with an outpatient status, a dextrose infusion could be administered at an infusion therapy clinic. Blood glucose monitoring is recommended to prevent hyperglycemia that could increase postoperative infec-

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**Table 1. McArdle Disease Complications and Anesthetic Considerations**

<table>
<thead>
<tr>
<th>McArdle disease complication</th>
<th>Anesthetic considerations</th>
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</thead>
<tbody>
<tr>
<td>Malignant hyperthermia</td>
<td>Contact MHAUS for recommendations. Consider anesthesia machine preparation. Maintain nontriggering agents. Be aware that CHCT results may not be reliable.</td>
</tr>
<tr>
<td>Anaerobic glycolysis</td>
<td>Continue IV dextrose infusion until patient can take complex carbohydrates orally. Monitor blood glucose, lactate, and potassium values.</td>
</tr>
<tr>
<td>Oliguria</td>
<td>Increase fluid and mannitol administration. Consider furosemide administration. Prepare immediate access to antiarrhythmic medications.</td>
</tr>
</tbody>
</table>

**Condition**

<table>
<thead>
<tr>
<th>Weak evidence</th>
<th>Strong evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noonan syndrome</td>
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</tr>
<tr>
<td>Osteogenesis imperfecta</td>
<td>x</td>
</tr>
<tr>
<td>Arthrogryposis</td>
<td>x</td>
</tr>
<tr>
<td>King-Denborough syndrome</td>
<td>x</td>
</tr>
<tr>
<td>CPT II deficiency</td>
<td>x</td>
</tr>
<tr>
<td>Myophosphorylase B deficiency</td>
<td>x</td>
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<tr>
<td>Myoadenylate deaminase deficiency</td>
<td>x</td>
</tr>
<tr>
<td>Brody disease</td>
<td>x</td>
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<tr>
<td>Idiopathic hyperCKemia</td>
<td>x</td>
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</tbody>
</table>

**Table 2. Evidence for MHS**

Reported cases of malignant hyperthermia and contracture test results that have been published in the context of coexisting enzymopathies and syndromes.

Abbreviations: MHS, malignant hyperthermia susceptibility; CPT II, carnitine palmitoyltransferase II; CK, serum creatinine kinase.

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tion risk and delay wound healing. If time permits, an awake fiberoptic method warranted. If time permits, an awake fiberoptic method is preferred, followed by a non-MH trigger technique, is rapid sequence induction using rocuronium to prevent route, but if general anesthesia is emergently required, a fluid deficits and third-space losses. In this case, blood glucose checks occurred hourly via arterial blood gases without any intervention necessary. Healthcare providers also paid particular attention to potassium and lactate values, as elevation could indicate muscle breakdown.

If decreased urine output occurs, increasing hydration and mannitol administration is recommended to improve tissue perfusion. If dark, cola-colored myoglobinuria occurs, rhabdomyolysis should be suspected and aggressive fluid resuscitation initiated. Fleisher reported substantial hyperkalemia that occurred in select case reports and that improved when treated with diuretics such as furosemide. Also, immediate access to antiarrhythmic medications is advised.

According to Lobato et al., a patient underwent cardiopulmonary bypass and, after receiving protamine, suffered an adverse reaction that resulted in hyperthermia, noncardiogenic pulmonary edema, rhabdomyolysis, and death. A skeletal muscle biopsy later showed accumulation of tissue glycogen consistent with undiagnosed McArdle disease. It is unclear at this time whether a link to McArdle disease, cardiopulmonary bypass, and/or adverse protamine reactions can be made. This literature recommends a heightened awareness for potential complications in patients with McArdle disease during the high-energy demands of cardiopulmonary bypass or who require protamine for heparin reversal.

In the pregnant population, McArdle disease has been researched for complications and proved relatively uneventful. Regional anesthesia is still the recommended route, but if general anesthesia is emergently required, a rapid sequence induction using succinylcholine to prevent fasciculations, followed by a non-MH trigger technique, is warranted. If time permits, an awake fiberoptic method is a safe option for intubation of the difficult maternal airway for general anesthesia as well. Also, if dextrose infusions are to be used, careful titration is important to prevent hyperglycemia-induced maternal and fetal complications.

**Conclusion**

 Providing general anesthesia for a patient with a diagnosis of McArdle disease is a critical time for healthcare providers, who must consider many aspects of the patient’s disease in order to safely manage his or her anesthesia. An organized approach to reviewing current literature is paramount. It is imperative that a heightened awareness for malignant hyperthermia, rhabdomyolysis, renal failure, electrolyte abnormalities, and thermoregulation is recognized, prepared for, and individualized to each patient.

Communication between anesthesia providers, MHAUS, the surgical team, the nursing staff, and the patient appears as a major underlying theme in the literature in order to deliver successful patient care. Also, a strong knowledge base of pharmacologic actions of intravenous fluids, diuretics, and muscle relaxants is of great importance.

Although McArdle disease is rare, the potential risks provide implications for vigilant anesthesia providers. Understanding of the anatomy, physiology, and pathology of McArdle disease remains essential for clinical practice. Furthermore, the limited literature in regard to anesthesia management of patients with McArdle disease should be expanded. McArdle disease is manageable, even in severe cases, provided that all medical, surgical, and anesthesia obstacles are recognized and evaluated for best practice methods.

**REFERENCES**


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