Review Article

Prevention of Rhabdomyolysis in Bariatric Surgery

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Background: Rhabdomyolysis (RML) is a clinical and biochemical syndrome caused by skeletal muscle necrosis that results in extravasation of toxic intracellular contents from the myocytes into the circulatory system. Postoperative RML in bariatric surgery occurs with various non-physiological surgical positions, with prolonged muscle compression. The potential consequences may lead to death. The purpose of this study is to review its pathophysiology and the best ways to prevent RML in bariatric surgery.

Methods: We searched the literature and reviewed all relevant articles, by searching for the keywords: rhabdomyolysis, morbid obesity, prevention and bariatric surgery, giving a total of 39 articles.

Results: Prevention may be enhanced by careful padding on the operative table at all pressure-points. Changing patient position, both intraoperatively and postoperatively, also reduces RML. A potential new solution to decrease the longer operative time and avoid RML is to perform the bariatric operation in two stages. Another way to limit the duration of surgery in high-risk patients is to alert surgeons not to select super-obese high-risk patients early in the learning curve.

Conclusion: As RML is an important and potentially fatal complication of bariatric surgery, the best way to avoid it is effective prevention. More research on this subject is necessary.

Key words: Rhabdomyolysis, bariatric surgery, morbid obesity, prevention, renal failure

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Introduction

Obesity is a complex and multifactorial disease influenced by psychological, genetic endocrine-metabolic and ambiental interaction.[1,2] Morbid obesity causes physical, emotional, economic and social problems.[3] Currently, >60% of Americans are overweight, and 12 million people in the USA are morbidly obese, defined as a body mass index (BMI) >40 kg/m^2.[4,5] In Brazil, the number of morbidly obese adults and children increases daily and ≈30% of the Brazilian population is overweight.[3] Obesity is a worldwide epidemic, and the obese have a nearly 12 times higher risk of premature death.[6,7] Health-care costs are 44% greater among severely obese patients, representing a public health problem in developed and developing countries.[4,8]

At present, the only available therapeutic intervention that provides effective long-term weight loss for morbid obesity is bariatric surgery.[4,9-13]

An unusual event that is a potentially fatal complication of bariatric surgery is rhabdomyolysis (RML).[14] This clinical and biochemical syndrome caused by skeletal muscle necrosis, results in extravasation of toxic intracellular contents from the myocytes into the circulatory system.[15-20] Postoperative RML in bariatric surgery is an event which occurs with various non-physiological surgical positions and prolonged muscle compression.[21] If prevention is not done, or the diagnosis is delayed, and appropriate treatment is not instituted, serious complications and even death can occur. We

evaluated the best ways to prevent RML in obesity surgery and its pathophysiology.

Materials and Methods

PubMed, Medline, Bireme, Scielo and Lilacs library, besides textbooks, specialized journals, and internet were searched between June and January 2005. The research was made by searching for the key words: "rhabdomyolysis OR rhabdomyolysis AND obesity AND surgery OR rhabdomyolysis AND morbid OR obesity". A total of 39 articles were obtained and appraised.

Published Results

Pathophysiology of Rhabdomyolysis (RML)

RML is the dissolution of striated muscle of any part of the human body which results in the release of muscle cell constituents into the extracellular fluid and circulation (Figure 1). Its consequence is the development of a nonspecific clinical and biochemical syndrome, harmful to the human organism.[1,15,22,23]

Myocytes in physiological form show a typical distribution of intra- and extracellular ions, which is critical to the maintenance of normal function. Ions in the body are either predominantly intracellular or extracellular; none of these have the same distribution.[22]

Three important mechanisms maintain the distinction between intracellular and extracellular molecules. *First* is the cell membrane; damage to this essential structure allows intracellular contents to escape and extracellular contents to enter.[24] *Second* is the sodium-potassium pump, which plays an important role in preserving essential intracellular and extracellular electrolyte distribution.[25] *Third*, cell membranes can also be disrupted as a consequence of severe electrolyte imbalances.[25,26]

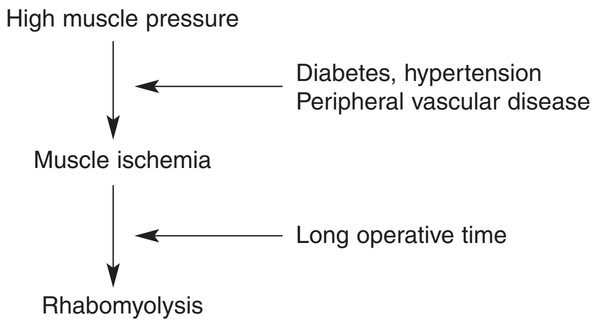

Figure 1. Pathogenesis of rhabdomyolysis in bariatric surgery.[14]

Muscular injury leads to disruption of the internal cellular structures of muscle cells. Cells with damaged membranes allow the uncontrolled influx of sodium, chloride, calcium and water down their electrochemical gradients. Large amounts of intravascular fluid (up to 12 liters) can leave the circulation and become sequestered as edematous fluid in damaged muscle tissue. This fluid shift produces an intravascular hypovolemia and subsequently hemodynamic instability.[27,28] The dramatic decrease in plasma volume leads to vasoconstriction, prerenal failure and, eventually, acute intra-renal failure.[23] Chloride and calcium also enter the cells, causing serum hypocalcemia and calcium deposition in skeletal muscle and renal tissues.[29]

Among the intracellular components that leak out of damaged skeletal muscle, the most immediately important one is potassium. Because this electrolyte is moving from an intracellular area of high concentration into the serum, where a low concentration is normal, lethal hyperkalemia can develop rapidly with cardiotoxic effects and dysrhythmias.[30] Phosphate also leaves the cells, producing hyperphosphatemia. Injured myocytes also leak lactic acid and other organic acids, promoting metabolic acidosis and aciduria. Purines released from disintegrating cells are metabolized to uric acid and can lead to hyperuricemia.[22,31]

Myoglobin is an oxygen-carrying molecule that gives muscles their red-brown color. Lysis of as little as 100 g of skeletal muscle results in myoglobinuria. Myoglobin is also nephrotoxic in patients with concomitant oliguria and aciduria.[22,24]

Thromboplastin and tissue plasminogen are released from injured muscle tissue, making patients with RML susceptible to disseminated intravascular coagulation, mainly when associated with sepsis.[24,25,28,31-33] RML also produces extreme increases in serum levels of creatinine phosphokinase (CPK). CPK has no toxic effects, and elevated plasma CPK

levels are simply a marker of increased permeability of muscle membranes. However, high values are pathognomonic for RML, because no other condition will lead to such extreme CPK elevations.[34]

Rhabdomyolysis in Bariatric Surgery

RML in bariatric operations is caused by tissue compression with extended periods of immobilization. This leads to muscle ischemia which interferes with oxygen delivery to the cells, thereby limiting production of adenosine triphosphate (ATP) and function of sodium-potassium membrane pumps. Therefore, serious complications such as hyperkalemia, hypocalcemia, hyperphosphatemia, compartment syndrome, disseminated intravascular coagulation (DIC), cardiac disorders, acute renal failure (ARF) and death may occur. Animal studies have demonstrated myonecrosis when an intracompartimental pressure of 30 mmHg was applied for 4-8 hours.[22] Recognized risk factors for the development of postoperative RML are prolonged duration of operation, massive obesity, surgical compressive positioning and endocrine or metabolic disorders such as diabetes and hypertension. Another cause is peripheral vascular disease which is a predisposing factor for compartmental syndrome.[35]

Long duration of surgery promotes more tissue compression and ischemia. RML has occurred after operations in non-obese patients when the surgery was >7 hours. Obese patients are at risk during shorter operative procedures (<7 hours). Obesity increases tissue compression,[1] where the weight is >30% above ideal weight.[21] RML is a complication of various non-physiological positions, eg. the seated, lateral decubitus, prone, exaggerated or high lithotomy, genupectoral, knee-chest or tucked, supine and hyperlordotic positions.[36-38] Super-obese male patients (BMI >50) with hypertension, diabetes and peripheral vascular disease are at greater risk for RML. These factors are not independent: super-obese male patients are more likely to be diabetic and hypertensive, and bariatric surgery in this population may be more difficult and likely to be associated with longer duration of operations and consequently more tissue compression. Other potential etiologic factors include family history of muscle disease and the consumption of certain drugs, notably anti-cholesterol statins.

Prevention of Rhabdomyolysis in Bariatric Surgery

Prevention of RML avoids serious outcomes of this important complication (Table 1). Bostanjain et al[21] concluded that prevention is enhanced by careful padding on the operative table. The same opinion is shared by Mognol et al[14] who agree that in morbidly obese patients, prevention includes adequate padding at all pressure-points during surgery. Khurana et al[9] advise protective padding added around the hips, shoulders and buttocks (areas adjacent to bone prominences) to minimize the surface and deeper pressure, by distributing pressure over a greater surface area.[9] Iseri et al[36] suggest the use of pneumatic beds during surgery to prevent the occurrence of RML.

Hofmann and Stoller[37] point out that obese surgical patients can position themselves on the surgical table before induction of anesthesia, to the most appropriate position, avoiding positions that can increase muscle compression. These authors also suggest the use of two combined surgical tables to decrease the pressure on the back surface of the massively obese patient.

Wiltsnire et al[38] recommend that special attention be given to protect injured and uninjured muscle tissue in the morbidly obese patient. This can be achieved by frequently changing patient position, both intraoperatively (for operations lasting >2-3 hours) and postoperatively. Bocca et al[39] also assert that preventive measures such as good positioning[9] and peroperative repositioning of the patient can prevent RML.

Bostanjian et al[21] emphasize that the duration of

Table 1. Prevention of Rhabdomyolysis in Bariatric Surgery

Padding pressure areas
Use of pneumatic beds during operation
Use of two combined surgical tables
Optimal position on surgical table
Limit surgical time :
• Reduce weight before bariatric surgery or perform surgery in two stages
• Avoid early in the learning curve
Changing patient position intra- and postoperatively
Aggressive fluid replacement peri-operatively
Early ambulation
Discontinue statin therapy
Correct risk factors for RML after surgery (Table 2)

immobilization is greater for very heavy patients. This is not only because the operation takes longer but also because other aspects of the operation including the placement of central lines or arterial lines are more likely to be difficult and time-consuming. The longer the immobilization, the greater is the RML risk, so one potential new solution proposed by Regan et al[40] and others[41] is to decrease the longer operative time by dividing the procedure into two stages, doing a gastric sleeve resection initially, and then when the patient has lost considerable weight performing the definitive bypass. Regan's group[40] concluded that laparoscopic sleeve gastrectomy with second-stage Roux-en-Y gastric bypass is feasible and effective. This two-stage approach is a reasonable alternative for surgical treatment of the high-risk super-super-obese (BMI >60) patient. Mognol et al[14] state that the gastric bypass in two stages is ideal for the morbidly obese hypertensive male with type II diabetes.

Another way to limit the duration of surgery in high-risk patients is alerting surgeons early in their learning curve not to select patients who fall into this group, or to offer such patients a staged procedure.[21]

Aggressive fluid replacement after surgery is another means of preventing RML.[14,23] For Iseri et al,[36] a high urine output should be instituted with the administration of IV fluids and diuretics, before, during and after surgery.

Discussion

RML has a variety of etiologies, the most common ones being alcohol abuse, use of illegal drugs, some medicines, and muscle compression. The latter is the main cause of RML with bariatric operations. Because of the increase in the number of bariatric operations not just in Brazil, but all over the world,[42] an increasing interest in RML as a bariatric surgical complication has been demonstrated.

Reducing the body weight before bariatric surgery may decrease the duration of surgery. It can be accomplished by hypocaloric diets, physical activity and endoscopic intragastric balloon.[41,43] In our experience, the latter is ideally the best way to perform bariatric surgery in super-super obese patients, not submitting them to the risks of two different surgical procedures, if adequate preoperative weight loss can be achieved.

Cholesterol-lowering agents also promote myolysis. As obese patients usually have elevated cholesterol, many are on statins at the time of surgery. This may increase the risk of muscle damage, with the other associated factors – elevated BMI, lengthy surgery, peripheral vascular disease, and metabolic disorders. Statins are first-line drugs for prevention and treatment of hypercholesterolemia and atherosclerotic disease. Although statins are generally well-tolerated and have a positive impact on human health, their myotoxic properties should keep physicians on alert. Mechanisms of statin-induced myopathy are still not fully understood. Phenotypic characteristics of patients, individual statin properties, and metabolic interaction with other drugs are important factors that may increase risk for statin myopathy. Thus, when the morbidly obese patient is to undergo a bariatric operation and is on statins, he/she should be alerted to stop therapy for a period. However, in the study of Bostanjian at al,[21] there was no difference in RML risk between patients who used cholesterol-lowering agents and those who did not. Prospective studies are necessary to prove the relation between 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase inhibitors and RML in bariatric surgery.

Another way to prevent RML is to protect injured and uninjured muscle tissue in the obese patient. This can be achieved by frequently changing the surgical position and encouraging early ambulation. At the São Rafael hospital, we ask the anesthesiologist to change the position each hour; if the patient is very heavy (super-super-obese), this is done every 30 minutes.

A strategy developed by our bariatric research team is an intermitent compression pneumatic bed (Figure 2). The pneumatic bed was designed to promote intermittent compression of the dorsal region of patients submitted to bariatric surgery or in a long-term hospital stay, with the purpose of preventing posterior tissue compression, mainly in buttocks, lumbar region and shoulders, avoiding ulcers and RML.

Other risk factors should be corrected to prevent RML after surgery (Table 2). They are hypoalbuminemia, hyperkalemia or hypophosphatemia, sepsis, CPK peak >6,000 IU/l, systemic arterial hypertension, diabetes, and pre-existing azotemia.[14]

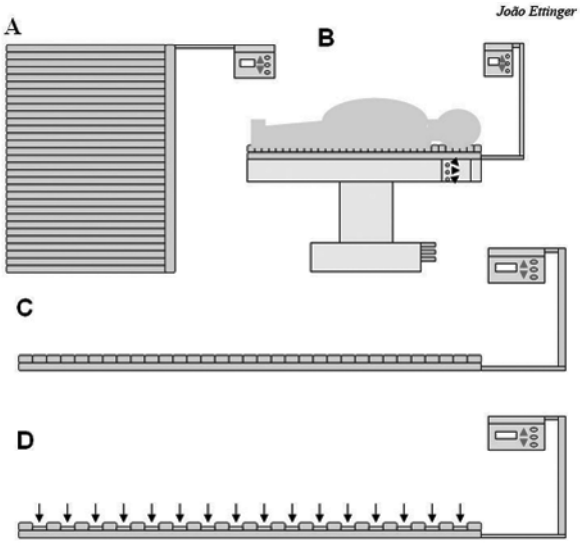

Figure 2. Intermittent Compression Pneumatic Bed. **A:** Superior view. **B:** Obese patient lying on bed. **C:** Bed with the compressor turned off. **D:** Bed with the compressor turned on. The pump inflates alternating units, and after 5 minutes deflates and inflates the others.

Conclusion

Because rhabdomyolysis a major, potentially fatal complication of bariatric surgery, the best deterrent is padding all pressure-points during surgery, changing patient position, decreasing longer operative duration by preoperative weight reduction or staging, alerting surgeons early in their learning curve not to select patients who fall into the RML risk group, and providing aggressive and reasonable fluid replacement. More research is necessary regarding RML prevention.

Table 2. Risk factors for acute renal failure from rhabdomyolysis after bariatric surgery[14]

Hypoalbuminemia
Hyperkalemia or hypophosphatemia
Sepsis
CPK peak >6,000 IU/l
Hypertension
Diabetes
Pre-existing azotemia

References

1. Sauret JM, Marinides G, Want GK. Rhabdomyolysis. Am Fam Physic 2002; 65: 907-12.
2. Silva FML, Silva MMML. A Obesidade na Sociedade Moderna. Journal Brasileiro de Medicina 2004; 87: 38-42.
3. Ilias EJ, Kassab P. Cirurgia da obesidade mórbida. Opinião do Especialista, Diálogo Científico 2004; 1: 9-10.
4. Herron DM. The surgical management of severe obesity. Mt Sinai J Med 2004; 71: 63-71.
5. Mokdad AH, Serdula MK, Dietz WH et al. The spread of the obesity epidemic in the United States, 1991-1998. JAMA 1999; 282: 1519-22.
6. Alberto C, Junior WR. In: Junior ABG, ed. Cirurgia da Obesidade, 1ª ed. São Paulo: Editora Atheneu 2002: 19-23.
7. Thirlby RC, Randall J. A Genetic "obesity risk index" for patients with morbid obesity. Obes Surg 2002; 12: 25-9.
8. Quesenberry CP Jr, Caan B, Jacobson A. Obesity, health services use, and health care costs among members of a health maintenance organization. Arch Intern Med 1998; 158: 466-72.
9. Khuara RN, Baudendistel TE, Morgan EF et al. Postoperative rhabdomyolysis following laparoscopic gastric bypass in the morbidly obese. Arch Surg 2004; 139: 73-6.
10. Rubenstein RB. Laparoscopic adjustable gastric banding at a U.S. center with up to 3-year follow-up. Obes Surg 2002; 12: 380-4.
11. Brolin RE, Kenler HA, Gorman JH et al. Long-limb gastric bypass in the superobese: A prospective randomized study. Ann Surg 1992; 215: 387-95.
12. Fisher BL, Schauer P. Medical and surgical options in the treatment of severe obesity. Am J Surg 2002; 184: 9S-16S.
13. Steinbrook R. Surgery for severe obesity. N Engl J Med 2004; 350: 1075-9.
14. Mognol P, Vignes S, Chosidow D et al. Rhabdomyolysis after laparoscopic bariatric surgery. Obes Surg 2004; 14: 91-4.
15. Lane R, Phillips M. Rhabdomyolysis. BMJ 2003; 30; 327 (7413): 115-6.
16. Criner JA, Appelt M, Coker C et al. Rhabdomyolysis: the hidden killer. Medsurg Nurs 2002; 11: 138-43.
17. Sulowicz W, Walatek B, Sydor A et al. Acute renal failure in patients with rhabdomyolysis. Med Sci Monitor 2002; 8: 24-7.

18. Vanholder R, Sever M, Erek E et al. Rhabdomyolysis. J Am Soc Neph 2000; 11: 1553-61.
19. Zager RA. Rhabdomyolysis and myohemoglobinuric acute renal failure. Kidney Int 1996; 49: 314-26.
20. Torres-Villalobos G, Kimura E, Mosquedo JL et al. Pressure-induced rhabdomyolysis after bariatric surgery. Obes Surg 2003; 13: 306-13.
21. Bostanjian D, Anthone GJ, Hamoui N et al. Rhabdomyolysis of gluteal muscles leading to renal failure: a potentially fatal complication of surgery in the morbidly obese. Obes Surg 2003; 13: 302-5
22. Criddle LM. Rhabdomyolysis. Pathophysiology, recognition, and management. Crit Care Nurs 2003; 23: 14-22, 24-6, 28 passim; quiz 31-2.
23. Collier B, Goreja MA, Duke III BE. Postoperative rhabdomyolysis with bariatric surgery. Obes Surg 2003; 13: 941-3.
24. Haskins N. Rhabdomyolysis and acute renal failure in intensive care. Nurs Crit Care 1998; 3: 283-8.
25. Slater MS, Mullins RJ. Rhabdomyolysis and myoglobinuric renal failure in trauma and surgical patients: a review. J Am Coll Surg 1998; 186: 693-716.
26. Moghtader J, Brady WJ Jr, Bonadio W. Exertional rhabdomyolysis in an adolescent athlete. Pediatr Emerg Care 1997; 13: 382-5.
27. Abassi A, Hoffman A, Better O. Acute renal failure complicating muscle crush injury. Semin Nephrol 1998; 18: 558-65.
28. Cheney P. Early management and physiologic changes in crush syndrome. Crit Care Nurs Q 1994; 17: 62-73.
29. Russel TA. Acute renal failure related to rhabdomyolysis: pathophysiology, diagnosis and collaborative management. Nephrol Nurs J 2000; 27: 567-77.
30. Gronert GA. Cardiac arrest after succinylcholine: mortality greater with rhabdomyolysis than receptor upregulation. Anesthes 2001; 94: 523-9.
31. Curry SC, Chang D, Connor D. Drug- and toxin-induced rhabdomyolysis. Ann Emerg Med 1989; 18: 1068-84.
32. Hollenstein U, Thalhammer F, Burgmann H. Disseminated intravascular coagulation (DIC) and rhabdomyolysis in fulminant varicella infection – case report and review of the literature. Infection 1998; 26: 306-8.
33. Riggs JE, Schochet SS Jr, Parmar JP. Rhabdomyolysis with acute renal failure and disseminated intravascular coagulation: association with acetaminophen and ethanol. Mil Med 1996; 161: 708-9.
34. Dayer-Berenson L. Rhabdomyolysis: a comprehensive guide. Nephrol Nurs J 1994; 21: 15-8.
35. Gorecki PJ, Cottam D, Ger R et al. Lower extremity compartment syndrome following a laparoscopic Roux-en-Y gastric bypass. Obes Surg 2002; 12: 289-91.
36. Iseri C, Senkul T, Reddy PK. Major urologic surgery and rhabdomyolysis in two obese patients. Int J Urol 2003; 10: 558-60.
37. Hofmann R, Stoller ML. Endoscopic and open stone surgery in morbidly obese patients. J Urol 1992; 148 (3 Pt 2): 1108-11.
38. Wiltshire JP, Custer T. Lumbar muscle rhabdomyolysis as a cause of acute renal failure after Roux-en-Y gastric bypass. Obes Surg 2003; 13: 306-13.
39. Bocca G, van Moorselaar JA, Feitz WF et al. Compartment syndrome, rhabdomyolysis and risk of acute renal failure as complications of the lithotomy position. J Nephrol 2002; 15: 183-5.
40. Regan JP, Inabnet WB, Gagner M et al. Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super-obese patient. Obes Surg 2003; 13: 861-4.
41. Milone L, Strong V, Gagner M. Laparoscopic sleeve gastrectomy is superior to endoscopic intragastric balloon as a first stage procedure for super-obese patients (BMI ≥50). Obes Surg 2005; 15: 612-7.
42. Buchwald H, Williams SE. Bariatric surgery worldwide 2003. Obes Surg 2004; 14: 1157-64.
43. Busetto L, Segato G, De Luca M et al. Preoperative weight loss by intragastric balloon in super-obese patients treated with laparoscopic gastric banding. Obes Surg 2004; 14: 671-6.

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