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RESEARCH ARTICLE

Clinical Features of Rhabdomyolysis After Open and Laparoscopic Roux-en-Y Gastric Bypass

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Abstract
Background Rhabdomyolysis (RML) is caused by muscle injury, this may cause kidneys overload and lead to acute renal failure (ARF). The risk factors for RML in bariatric surgery (BS) are operative time (OT) >4 h and high BMI. The frequency of RML in BS varies from 12.9 to 37.8%. This study has the objective of describing the characteristics associated with RML and ARF in BS.
Methods We studied retrospectively 114 patients submitted to BS. Criteria for RML were CPK level >950 IU/l (five times the normal value). The variables were BMI, OT, age, intraoperative hydration and diuresis, CPK, creatinine, arterial hypertension, peripheric vascular disease, diabetes, open and laparoscopic techniques—inclusion criteria: patients submitted to gastric bypass; exclusion: renal failure and statins use.
Results RML incidence was 7%. The factors associated with RML in the bivariate analysis were hepatic steatosis, high BMI, high weight, higher excess weight, and prolonged OT. The risk factor for RML in the multivariate analysis was BMI≥50 kg/m^2. When the OT was below 2 h the incidence of RML was zero, but this was not significant in the multivariate analysis. The factors associated with a higher risk of CPK elevation (multivariate analysis) were hypertension and open technique.
Conclusion BS is safe, with low incidence of RML/ARF. High BMI is associated with a higher risk of RML. Probably a longer OT is associated with a higher risk of RML not statistically demonstrated in this study. The factors associated with a higher risk of CPK elevation were hypertension and open technique.

Keywords Rhabdomyolysis · Acute renal failure · Acute tubular necrosis · Gastric bypass · Laparoscopic · Open bariatric surgery · Morbid obesity · CPK · BMI · Operative time

Abbreviations

BS	bariatric surgery
RML	rhabdomyolysis
ARF	acute renal failure

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OT	operative time
HSR	Hospital São Rafael
HC	Hospital Cidade
CPK	creatine phosphokinase
ORYGBP	open Roux-en-Y gastric bypass
LRYGBP	laparoscopic Roux-en-Y gastric bypass
LAGB	laparoscopic adjustable gastric banding
SD	standard deviation
CI	confidence interval
BMI	body mass index
OR	operating room
DS	duodenal switch

Introduction

Morbidly obese patients submitted to bariatric surgery (BS) may develop several postoperative complications [1]. Rhabdomyolysis (RML) is a dangerous postoperative complication for these individuals and a well-known cause of acute renal failure (ARF). RML is frequently caused by ischemia/reperfusion or crush injury. Very obese patients submitted to prolonged operations are also at risk of muscle necrosis with consequently ARF due to elevated pressure in the muscles leading to RML and the creation of compartment syndrome [2]. RML is a clinical and biochemical syndrome resulting from injury to skeletal muscle, which compromises the integrity of the sarcolemmal membrane. Loss of sarcolemmal integrity allows the release of intracellular proteins into the circulation, and if diagnosis is delayed and appropriate treatment is not instituted, serious complications such as hyperkalemia, hypocalcaemia, hyperphosphatemia, compartment syndrome, cardiac dysrhythmias, disseminated intravascular coagulation, acute renal failure, and even death can occur [3]. RML also can cause muscle necrosis and infection requiring debridement and drainage [2]. The incidence of RML in BS varies from 12.9 to 37.8% [4–7]. Preventive measures to avoid RML are padding pressure areas; use of pneumatic mattress during operation; use of two combined surgical tables in wider patients; optimal position on surgical table; limit surgical time by reducing weight before bariatric surgery or perform surgery in two stages); avoiding early in the learning curve selecting high-risk super-super-obese patients; changing patient position intra and postoperatively; aggressive fluid replacement perioperatively; early ambulation; discontinue statin therapy and correct risk factors for RML after surgery [8].

Our interest in this subject started after a successfully treated case of RML occurred in a super-obese patient submitted to open gastric bypass. We studied in this work the incidence and main characteristics of RML in patients submitted to gastric bypass.

Materials and Methods

A retrospective observational cohort study was performed. A series of 114 individuals submitted to open and laparoscopic Roux-en-Y gastric bypass during an 11-month period, from August 2005 to March 2006 was analyzed, all patients were operated at the Hospital São Rafael (HSR) & Hospital Cidade (HC), Salvador, Brazil. This study was approved by the Research and Ethics Committee. Every patient met the criteria set by the NIH Consensus Panel in 1991 [9], patients with a BMI$\geq$40 kg/m^2 or $\geq$35 kg/m^2 with co-morbidities. Standardized data of all patients were entered in a database. The variables recorded were age, gender, weight, excess weight, BMI, period of hospital stay, operative time, intra-operative fluids infusion (hydration) and diuresis, CPK, serum creatinine, bariatric technique approach (open or laparoscopic), and co-morbidities (arterial hypertension, diabetes, hepatic steatosis, peripheric vascular disease).

> Inclusion criteria: Male or female patients (18–65 years old), submitted to open (ORYGBP) or laparoscopic Roux-en-Y gastric bypass (LRYGBP).
> Exclusion criteria: Patients with renal failure, utilizing statins, with alcohol abuse.

Total serum CPK and creatinine were determined by using a diagnostic kit measured on a Vitros chemistry 950 analyzer (Ortho-Clinical Diagnosis).

The upper limit of normal CPK was 190 IU/l and for creatinine was 1.2 mg/dl. Rhabdomyolysis was defined as a postoperative value >950 IU/l (five times the upper normal limit) [4].

Excess weight (kg) was calculated with the formula EW=AW−IW, EW=excess weight, AW=actual weight, IW=ideal weight. IW=22×A^2, A=height (m) [10].

Surgical Technique

All subjects were submitted to ante-colic, ante-gastric banded Roux-En-Y Gastric Bypass (Fig. 1), via laparoscopy or laparotomy. The patients were placed on the surgical table with an adequate padding of the buttocks, lumbar region and shoulders to avoid muscular injuries. The operating table was made by Maquet® and was a special model designed for bariatric patients with a very thick and soft mattress. Patients were encouraged to choose the most comfortable position before the operation. When performing LRYGB the surgeon operated standing between the legs of the patient, and the intrabdominal pressure was set at the maximum level of 15 mmHg. All procedures were performed with the same standardization. All intra-operative events were recorded.

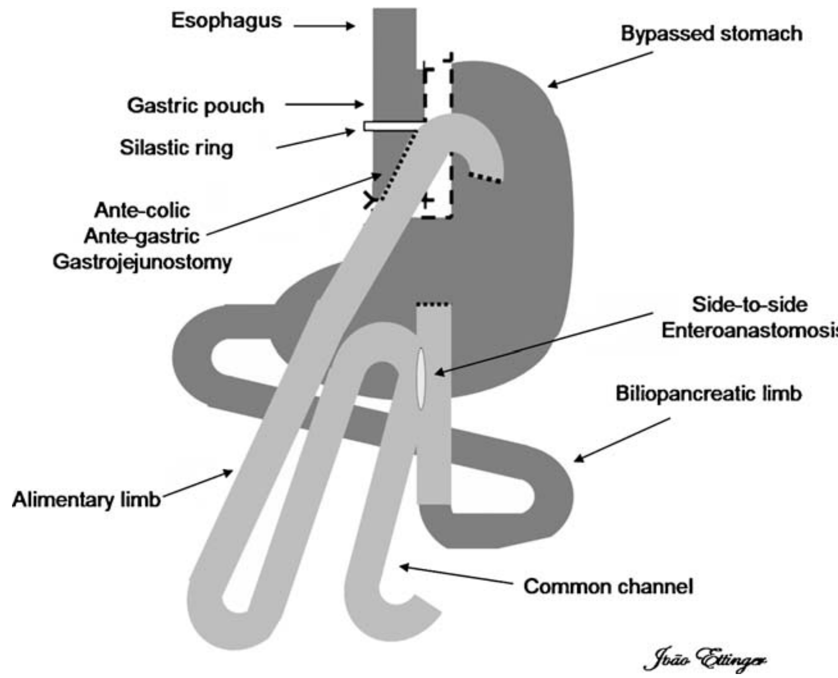

Fig. 1 Ante-colic ante-gastric banded Roux-en-Y gastric bypass

Perioperative Precautions

Prophylaxis of venous thrombosis was performed with heparin; we did not use intermittent compression of the legs, nor compressive stocks. Generous fluids administration was used. Antibiotic-prophylaxis was done with a single dose of Avalox®-400 mg.

Postoperative Care

Blood tests were performed after the operation, as well as serum creatinine and serum CPK levels.

Venous thrombosis prophylaxis was continued after hospital discharge with 40 mg of enoxaparin (Clexane®) subcutaneously for at least 10 days after the procedure.

Routine multivitamin and mineral supplementation was prescribed at least the first 2 years after operation and thereafter based on clinical, nutritional and laboratory evaluations. This supplementation includes daily multivitamin plus mineral complement and vitamin B_{12} supplementation intramuscularly at a dose of 1,000 mcg monthly. Calcium was prescribed in women routinely. The patients were followed-up by the surgeon and multidisciplinary team at frequent postoperative intervals to access possible

Table 1 Operative and postoperative data of 114 patients submitted to RYGBP

	114 Patients mean (variation)	SD	CI 95% (inferior L–superior L)
Age (years)	38.25(19–64)	10.93	35.44–41.06
BMI (kg/m^2)	43.1 (35–65.8)	5.23	41.75–44.45
Operative time (min)	176.7 (75–375)	45.45	165–188.4
Hospital stay (days)	2.7 (1–8)	1.12	2.41–2.99
Highest CPK value	400 (56–3863)	488.4	274.31–525.69
Weight (kg)	117.9 (88–197)	20.64	112.59–123.21
Height (m)	1.64 (1.42–1.87)	0.088	1.62–1.66
Excess weight (kg)	57.8 (35.26–131.16)	17.06	53.41–62.19
Ideal weight (kg)	60.04 (44.36–76.93)	6.47	58.37–61.71
Intra-operative hydration (ml/kg)	31.3 (6.7–53.9)	8.80	29.04–33.56
Intra-operative hydration (ml/kg/h)	11.2 (1.79–29.96)	4.16	10.13–12.27
Intra-operative diuresis (ml/h)	226 (28.57–800)	162.8	184.1–267.9
Intra-operative diuresis (ml/kg/h)	1.99 (0.23–7.77)	1.56	1.59–2.39
Preoperative creatinine (mg/dl)	0.79 (0.4–1.4)	0.17	0.75–0.83
1st postoperative day creatinine (mg/dl)	0.7 (0.2–1.3)	0.21	0.65–0.75

Table 2 Comparison between the ORYGBP and LRYGBP groups

	LRYGBP Mean/SD	CI 95%	ORYGBP Mean/SD	CI 95%	*P* value
Gender	40F/69% 18M/31%		46F/82% 10M/18%		
Age (Years)	36.9 (11.86)	33.85–39.95	39.6 (9.8)	37.08–42.12	>0.05
BMI (kg/m^2)	41.5 (4.12)	40.44–42.56	44.6 (5.8)	43.11–46.09	<0.05
Operative time (min)	171 (45.71)	159.24–182.76	182 (44.9)	170.44–193.56	>0.05
Hospital stay (days)	2.68 (1.35)	2.33–3.03	2.7 (0.84)	2.48–2.92	>0.05
Highest CPK value (IU/L)	313 (534)	175–450	490 (421)	381.65–598.35	<0.05
Weight (kg)	114.84 (17.14)	110.43–119.25	121.13 (23.45)	115.09–127.17	>0.05
Height (m)	1.66 (0.09)	1.64–1.68	1.63 (0.09)	1.61–1.65	>0.05
Excess weight (kg)	53.9 (12.67)	50.65–57.17	61.9 (19.96)	56.77–67.23	<0.05
Ideal weight (kg)	60.9 (6.34)	59.3–62.57	59.1 (6.54)	57.42–60.84	>0.05
Intra-operative hydration (ml/kg)	31.3 (10.48)	28.6–34	31.3 (6.72)	29.57–33.03	>0.05
Intra-operative hydration (ml/kg/h)	11.7 (5.10)	10.46–13.09	10.7 (2.85)	9.99–11.48	>0.05
Intra-operative diuresis (ml/h)	189.4 (156.6)	149.1–229.7	264.4 (161.6)	222.81–305.99	<0.05
Intra-operative diuresis (ml/kg/h)	1.69 (1.44)	1.32–2.06	2.31 (1.63)	1.89–2.73	<0.05
Preoperative creatinine (mg/dl)	0.79 (0.18)	0.74–0.84	0.79 (0.15)	0.75–0.83	>0.05
1st postoperative day creatinine (mg/dl)	0.66 (0.22)	0.6–0.72	0.75 (0.19)	0.70–0.80	<0.05

complications; operative reports, chart notes, discharge summaries and hospital records were also included. Nutritional, laboratory, and clinical evaluation were scheduled to be performed at 1, 3, 6, 9 and 12 months postoperatively and every year thereafter.

Statistical Analysis

Data are expressed as median or percentage. Confidence intervals of 95% were calculated. Comparisons between groups were performed using the Mann–Whitney and Wilcoxon tests for continuous variables and the Chi-square test and Fisher's exact test for categorical variables. Spearman's correlations coefficients were calculated to quantify associations between continuous variables. All statistical tests were two-tailed. Logistic regression was used to obtain multivariate association parameters (odds ratios) adjusted for confounders. *P* values<0.05 were considered statistically significant. Statistical analysis was performed using the SPSS for Windows data editor, version 10.0 (SPSS)

Results

A total of 114 bariatric patients submitted to open and laparoscopic RYGBP were studied. The subjects were divided in two groups: 56 patients (49.1%) underwent open Roux-en-Y Gastric Bypass (ORYGBP), and 58 patients

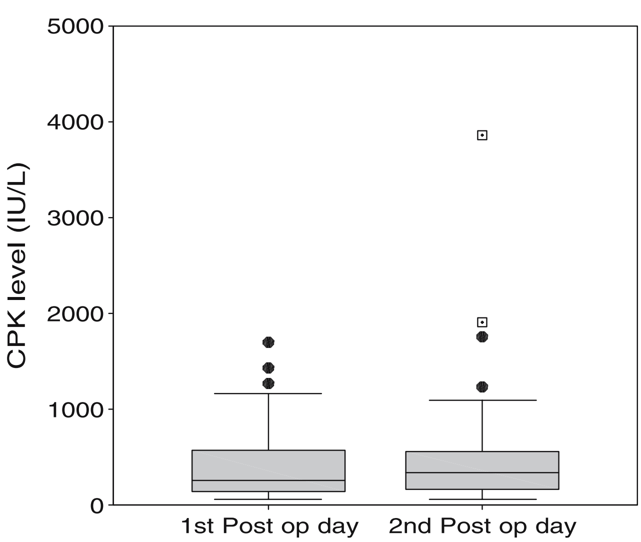

Fig. 2 Box-plot showing the highest CPK levels on the 1st and 2nd postoperative days

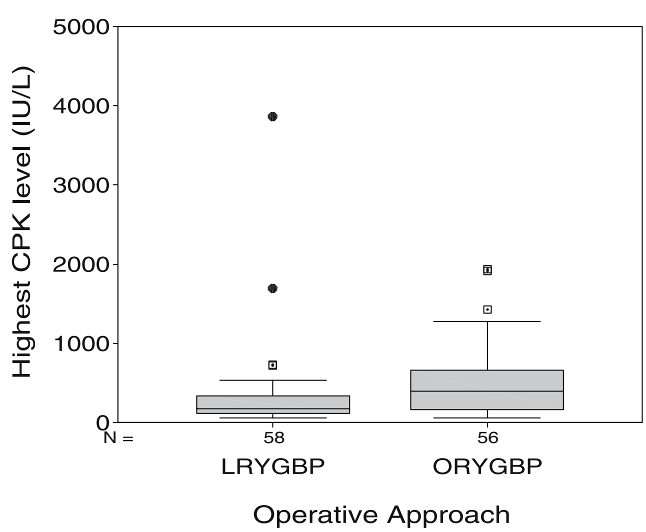

Fig. 3 Box-plot showing the highest CPK levels in the LRYGBP and ORYGBP groups

Table 3 Characteristics of the patients with RML—Total of 7 patients (8%)

	Mean	SD	CI 95% Inf. L–Sup. L	Min–Max
Age (years)	40.25	13.94	36.66–43.84	27–64
BMI (kg/m^2)	48.9	5.57	47.47–50.33	40–55.5
Weight (kg)	145.2	23.9	139.05–151.35	115–187
Excess weight (kg)	81.9	24.2	75.67–88.13	56.32–129.97
Operative time (min)	221.25	82.97	199.9–242.6	140–375
Highest CPK level (IU/L)	1776	913	1541–2010	952–3863
Intra-operative hydration (ml/kg)	27.7	9.09	25.36–30.04	6.71–34.76
Intra-operative hydration (ml/kg/h)	8.33	3.78	7.36–9.3	1.79–13.9
Intra-operative diuresis (ml/h)	171.7	68.1	154.17–189.23	66.67–300
Intra-operative diuresis (ml/kg/h)	1.23	0.67	1.06–1.4	0.45–2.31

(50.9%) were submitted to laparoscopic Roux-en-Y Gastric Bypass (LRYGBP). The patients' characteristics are shown on Table 1 and 2. Concerning the institutions, 62 patients (54.4%) were operated at the HSR and 52 patients (45.6%) at the HC. Three patients had another operation during the procedure; one had gastric band retrieve, another colecistectomy, and a third had gastrectomy due to gastric antrum metaplasy.

Overall operative and postoperative data are shown on Table 1. The second postoperative day had a higher mean CPK peak than the first postoperative day (Fig. 2). There were variables with statistically significant differences between the ORYGBP and LRYGBP groups as BMI, CPK peak (Fig. 3), excess weight, intra-operative diuresis, and first postoperative day creatinine (Table 2).

Complications

In this study, there was a case of difficult orotraqueal intubation in which it was necessary to use bronchoscopy. Three patients had postoperative arterial hypertension with difficult treatment. One patient had disfagia probably caused by gastrojejunostomy edema that led to delay on hospital discharge forcing her to stay 5 days at the ward. One patient was readmitted due to intrabdominal abscess that was drained by the radiologist via CAT scan. One patient stayed two more days at the hospital due to respiratory discomfort and had hospital discharge after 4 days. One patient slipped from the operating table after anesthetic induction falling in the OR floor; this caused interruption of the procedure, and after assuring there was

Table 4 Variables associated with RML in the bivariate analysis

	N	Without rhabdomyolysis	With rhabdomyolysis	Odds ratio	CI 95%	*P* value
Without liver steatosis	101	96/95%	5/5%	1.00		
With liver steatosis	13	10/76.9%	3/23.1%	5.76	1.195–27.757	0.047*
BMI stratum						0.004[a]
35 to 39.9 kg/m^2	30	30/100%	0			
40 to 49.9 kg/m^2	69	65/94.2%	4/5.8%	1.00		
≥50 kg/m^2	15	11/73.3%	4/26.7%	5.90	1.284–27.184	
Weight stratum						0.001[a]
≤110 kg	47	47/100%	0			
>110–140 kg	53	49/92.5%	4/7.5%	1.00		
>140 kg	14	10/71.4%	4/28.6%	4.9	1.046–22.943	
Excess weight stratum						0.028[a]
≤45 kg	25	25/100%	0			
>45–60 kg	51	49/96.1%	2/3.9%	1.00		
>60 kg	38	32/84.2%	6/15.8%	4.59	0.872–24.188	
Operative time stratum						0.027[a]
≤2 h	10	10/100%	0			
>2–4 h	98	92/93.9%	6/6.1%	1.00		
>4 h	6	4/66.7%	2/33.6%	7.67	1.161–50.628	
Total	114	106/93%	8/7%			

Reference stratum=1.00
*=Fisher test
[a] =Chi–square test

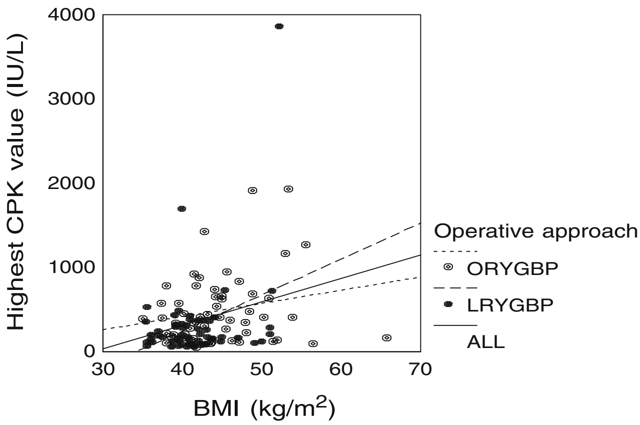

Fig. 4 Scatter plot of Highest CPK level versus BMI. r = 0.297 CPK = −795.048+27.74×BMI R2 = 0.088 P = 0.001. The CPK value was positively correlated with BMI

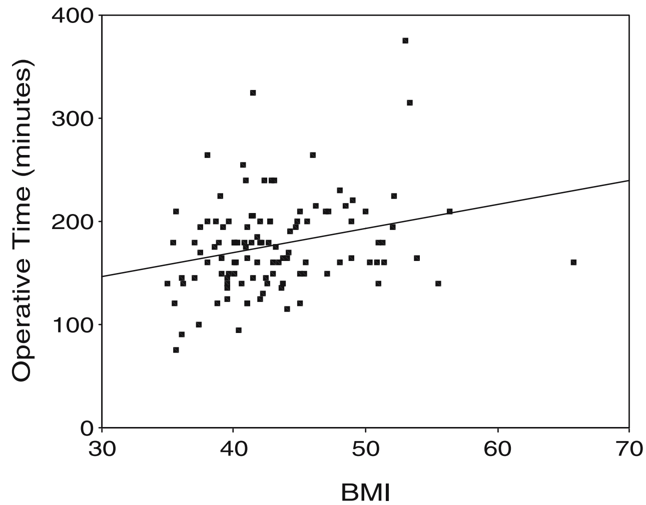

Fig. 6 Scatter plot of operative time versus BMI. r = 0.268 Operative time = 76.5+2.33×BMI R2 = 0.072 P = 0.004. The operative time was positively correlated with BMI

no injury in the patient, she was operated after 2 days. There was a case of LRYGBP conversion to ORYGBP due to an enlarged liver caused by hepatic steatosis leading to a complicated visualization of the stomach. There were four cases (3.5%) of intrabdominal bleeding and three cases (2.6%) of reoperation all in the LRYGBP group: one due to great omentum bleeding, and this patient developed RML with a CPK value of 1,694 IU/l he used 3 U of red blood cells, another patient had gastric vessels bleeding and used 2 U of red blood cells, and a third patient also had gastric vessels bleeding but did not use blood transfusion. All three patients were reoperated by laparoscopy; a fourth patient had bleeding via closed suction drainage and did not use transfusion. Furthermore, reoperation was not necessary. In the ORYGBP there was no hemorrhage. There were seven cases (8%) of RML (Table 3); none was severe, and there was no pain complain. There were four cases (3.5%) of pre-renal acute renal failure and all were resolved by vigorous hydration with saline solution. There was not any death or patients with sequelae in this series.

Bivariate and Multivariate Analysis

In bivariate analysis, we found five variables associated with RML: hepatic steatosis, high BMI, high weight, high excess weight, prolonged operative time (Table 4). CPK was positively correlated with BMI and long operative time (Figs. 4 and 5). Operative time was positively correlated with BMI (Fig. 6). CPK was inversely correlated with hydration in both operative groups (Fig. 7). The factors associated with the elevation of CPK in the bivariate analysis were arterial hypertension and open technique (Table 5).

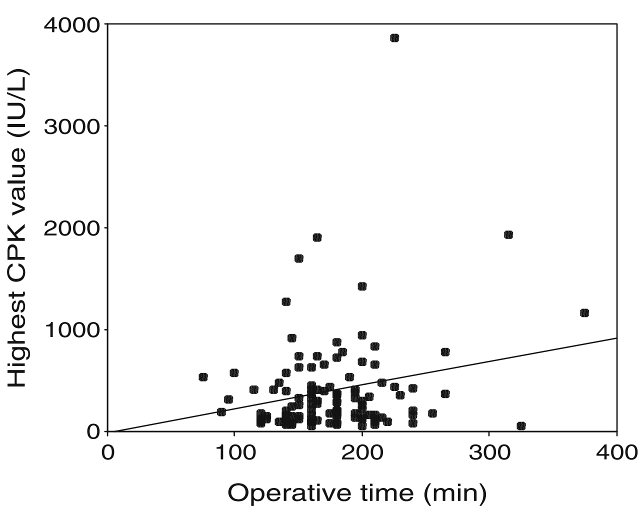

Fig. 5 Scatter plot of highest CPK level versus operative time. r=0.215 CPK = −6.95+2.3×operative time R2 = 0.046 P = 0.022. The CPK value was positively correlated with operative time

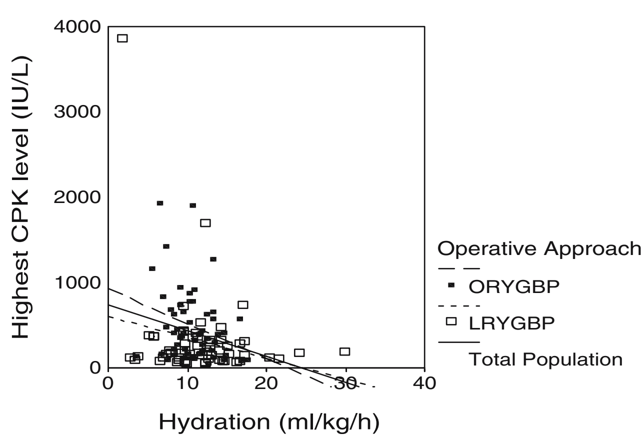

Fig. 7 Scatter plot of highest CPK value versus Hydration versus type of surgery. LRYGBP: r=−0.23 CPK=601.1−24.4×hydration R^2=0.054 P=0.039. ORYGBP: r=−0.27 CPK=926.6−40.62× hydration R^2=0.75 P=0.020. The CPK values were inversely correlated with hydration on both groups

Table 5 Variables associated with CPK elevation in the bivariate analysis

	N	Without CPK elevation	With CPK elevation	Odds ratio	CI 95%	*P* value
Without arterial hypertension	65	34/52.3%	31/47.7%	1.00		
With arterial hypertension	49	12/24.5%	37/75.5%	3.38	1.50–7.62	0.003[a]
Technique						0.012[a]
LRYGBP	58	30/51.7%	28/48.3%	1.00		
ORYGBP	56	16/28.6%	40/71.4%	2.67	1.23–5.81	
Total	114	46/40.4%	68/59.6%			

Reference stratum=1.00
*=Fisher test
[a] =Chi-square test

In multivariate analysis with logistic regression we found BMI≥50 kg/m^2 as the factor associated with a higher risk of RML. Operative time had a *P* value=0.08 without statistical significance for RML development (Table 6). The factors associated with the elevation of CPK in the multivariate analysis were hypertension and open technique (Table 7).

Discussion

Many surgeons develop the interest for the study and prevention of rhabdomyolysis in bariatric surgery after having seen this complication occurring in a patient [4].

This paper describes the clinical features associated with RML. We verified a rhabdomyolysis incidence of 7% characterized by values five times the upper normal limit [4]. There were no cases of severe rhabdomyolysis. This study showed the lowest incidence of RML in gastric bypass patients compared to other series (Table 8).

The factors associated with the development of rhabdomyolysis were hepatic steatosis, high BMI, high weight, high excess weight, prolonged operative time. The risk factor for RML development after RYGBP was BMI>50 kg/m^2. This is compatible with medical literature findings. There were not cases of RML with: BMI<40 kg/m^2, weight ≤110 kg, excess weight ≤45 kg and operative time ≤2 h. These are important findings that can be used clinically.

There was an increased tendency of RML in the open technique group with an incidence of 10.7% compared to 3.4% in the laparoscopic group. We could speculate that the ORYGBP would cause more muscle injury, but in our open approach, we do not cut the musculature, but only the fascia. Hiratsuka et al. [11] demonstrated in a study of open prostatectomy without muscle cutting that the elevations of CPK and myoglobin were proportional to the operative time as what happened in our study, but they found that in the operation with muscle cutting even with shorter operative times, there was a significantly increase of CPK and myoglobin not proportional simply to the operative time. We found important differences between the ORYGBP and LRYGBP that might have caused this increased trend of RML in the open group variables as mean BMI, mean CPK peak, and mean excess weight were higher in the open group with statistical significance.

The incidence of CPK above the normal value (190 IU/l) was 59.6%. We encountered 40.4% (46) with CPK values below 190 IU/l; 52.6% (60) with CPK levels between 190 to 950 IU/l and 7%(8) with CPK levels above 950 IU/l. In this study, we had a mean of hospital stay of 2.7 days this caused difficulty in the study of CPK levels curve.

We found four cases (3.5%) of pre-renal ARF in this work; all were reverted by vigorous hydration with recovery in less than 48 h. There was not any case of acute tubular necrosis and dialysis was not necessary. This diverges from the Sharma work [12] that had 2.3% (42) of ARF in 1,800 patients; however, in his study, six patients needed dialysis, and two needed permanent dialysis (Table 9). The factors associated with ARF in the bivariate analysis were hepatic steatosis, rhabdomyolysis and high levels of CPK. Multivariate analysis showed RML as a risk factor for the development of ARF. We considered that there was no temporary relation between RML and ARF because the CPK and creatinine measurements were performed on the same moment and day (1 measurement/day). We concluded that these data are insufficient to establish a causative relation between RML and ARF in this series.

Table 6 Risk factor for RML—Multivariate analysis/Logistic regression

Variable	Beta	Odds ratio	*P*	CI 95% Min–Max
BMI≥50 Kg/m^2	2.0166	7.51	0.0122	1.55–36.36
Operative time>4 h	1.8536	6.38	0.0805	0.80–51.00
Constant	−3.3371			

Table 7 Risk factors for CPK elevation—Multivariate analysis/Logistic regression

Variable	Beta	Odds ratio	*P*	CI 95% Min–Max
Arterial hypertension	1.144	3.14	0.0069	1.37–7.21
ORYGBP	0.8957	2.45	0.0287	1.10–5.46
Constant	–0.4808			

The shorter operative time caused a lower RML incidence compared to other series. When the mean operative time was below 3 h, the incidence of RML was less than 10%, and there was no severe RML. When the operative time was below 2 h, there was no RML. The elevated levels of CPK suggests that patients submitted to bariatric surgery have a high incidence of muscle compression, and a percentage of these patients will develop RML that can lead to ARF. Measures to diminish the CPK elevation (muscle compression) help to decrease the development of RML and consequently decrease ARF. Our data show that high BMI is associated with a higher RML risk.

Mognol et al. [4], Lagandré et al. [6], and Carvalho et al. [7] found the highest mean values of CPK on the first postoperative day. Faintuch et al. [5] found the highest CPK levels on the second postoperative day. This diverges from our study where we found the highest CPK values on the third postoperative day. We encountered a mean peak of CPK on the first postoperative day of 312 IU/l, on the second equal to 497 IU/l, on the third a mean of 684 IU/l, and on the fourth 468 IU/l; as the patients with RML stayed for a longer period in the hospital, this could have influenced this outcome resulting in a higher CPK value on the third day. It is important to emphasize that all CPK measurements were done while the patient remained in the hospital; because of this, the possibility to detect higher levels of CPK beyond the first postoperative day was not the same for all patients. Future studies will be performed to clarify this issue.

Khurana et al. [13] reported a mean surgical time of 4.1 h and a total mean anesthesia time of 5.6 h in 5 cases of RML after duodenal switch (DS). Bostanjian et al. demonstrated a 0.9% incidence of rhabdomyolysis, with a median peak serum CPK level of 26,000 IU/l in the patients with RML [2].

Table 8 Research articles about rhabdomyolysis in bariatric surgery

Author Journal	Year	N	Study type	Technique	Total RML	Mild RML CPK< 4000 UI/L	Severe RML CPK> 4000 UI/L	Operative time Mean–min	BMI Mean kg/m^2
Khurana et al Arch Surg	2004	353	Retrospective	Laparoscopic DS	–	Not studied	1.4% 5 patients	246	56 kg/m^2 Patients with RML
Mognol et al Obes Surg	2004	66	Prospective	LAGB× LRYGBP	22.7% 15 patients	15.2% 10 patients	7.5% 5 patients	110 LAGB 390 LRYGBP	43.9 kg/m^2 58.8 kg/m^2
Carvalho et al Obes Surg	2006	98	Prospective	ORYGBP	37.8% 38 patients	37.8% 38 patients	None	220	43.2 kg/m^2
Faintuch et al Obes Surg	2006	129	Retrospective	ORYGBP	12.9% 16 patients	8.5% 11 patients	3.8% 5 patients	320 mild RML 340 severe RML	50.8 kg/m^2 mild RML 54.6 kg/m^2 Severe RML
Lagandré et al Obes Surg	2006	49	Prospective	LAGB× intestinal bypass× RYGBP	26.5% 13 patients	24.5% 12 patients	2.04% 1 patient	195 without RML 272 with RML	49.7 kg/m^2
Ettinger et al Obes Surg Current study	2007	114	Retrospective	ORYGBP× LRYGBP	7% 8 patients	7% 8 patients	None	182 ORYGBP 171 LRYGBP 176 total	44.6 kg/m^2 ORYGBP 41.5 kg/m^2 LRYGBP 43.1 kg/m^2 Total

Table 9 Comparison with studies regarding ARF in bariatric surgery

Author Journal	Year	Study type	Technique	ARF	ARF needing dyalisis	ARF needing permanent dyalisis
Sharma et al SOARD	2006	Retrospective	LRYGBP	2.3% 42 patients	6 patients	2 patients
Ettinger et al Obes Surg	2007	Retrospective current study	ORYGBP and LRYGBP	3.5% 4 patients	Not necessary	Not necessary

Mognol et al. 2004 [4] performed a prospective study about rhabdomyolysis after laparoscopic bariatric surgery and reported 22.7% of RML, 6% in the group submitted to laparoscopic adjustable gastric banding (LAGB) and 75% in the group submitted to LRYGB, the last group had unusual long operative times, probably this led to this high rate of RML [4].

We elucidated a risk factor and five associated factors for RML; tendencies were shown and variables with clinical significance for RML were encountered. Our work also shows the differences in CPK elevation and RML in LRYGBP and ORYGBP. In the future, a multicenter study shall be performed with more patients, consequently with more power to assess risk factors for RML. It is likely that in our study, the low mean operative time (<3 h), the good amount of intravenous fluids used during the operations, the adequate mattress utilized, the comfortable positionement of the patient in the operative table, the early ambulation, and physiotherapy positively influenced the low incidence of RML and ARF. Routine postoperative measurement of CPK should be done in bariatric patients to early detect CPK elevation that could progress to RML, avoiding potential severe complications due to this syndrome. The CPK measurement is a cheap exam, easy to perform, and can be done in all hospitals that treat bariatric patients. We consider important the CPK dosage after bariatric operations. CPK measurement should be performed daily while the patient is in the hospital.

Conclusion

Our study showed that bariatric surgery is an efficient and safe method for treatment of morbid obesity, reporting low incidence of complications as RML and ARF. High BMI is associated with a higher risk of RML. Probably longer operative time is also associated with a higher risk of RML; however, this study was not able to show this association with statistical significance. The factors associated with a higher risk of CPK elevation were hypertension and open technique.

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