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Neuromuscular Blockade, Bariatric Surgeon Satisfaction, and Quality of Patient Recovery

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Abstract

Background: To date, little is known about neuromuscular blockade (NMB) and its impact in bariatric surgery and patient recovery. The goal of this study was to better assess the relationship between depth of NMB, bariatric surgeon's satisfaction, and the quality of patient recovery.

Methods: Between January and September 2015, we did a prospective observational study of 50 morbidly obese patients undergoing elective laparoscopic sleeve gastrectomy (LSG) under general anesthesia at our ambulatory surgical center. Rocuronium was used for tracheal intubation with bolus doses to maintain NMB. NMB was monitored at 5 minute intervals during the surgery, and at 30 second intervals following the reversal agent. The surgeon was blind to all anesthesia procedures and scored the surgical working conditions at 15 min intervals. Demographic data, operative data, and conditions were analyzed.

Results: 42 females and 8 males, with a mean age of 38.8 years (range: 19 to 60, standard deviation (SD): $\pm$ 9.2), and mean BMI of 43.9 (range: 36 to 58, SD: $\pm$ 5.1), underwent a LSG. Mean total surgical time was 63 minutes (range: 35 to 128). During the laparoscopic part of the surgery, 22% of the patients were in deep block and 78% were in moderate block. Six patients presented "poor" or "extremely poor" surgical conditions, and 6 patients had a sudden increase in intra-abdominal pressure. None of these patients were in deep block at that time. Patients in deep NMB had a shorter laparoscopic time (37 minutes, SD $\pm$ 7.1 vs 53 minutes, SD $\pm$ 18.3; P = 0.006).

Conclusions: This study found that deep NMB prevents inappropriate abdominal cavity movement, consequently improving the operating area and the surgeon satisfaction.

Keywords: Ambulatory Surgical Procedures, Bariatric Surgery, Length of Stay, Satisfaction, Neuromuscular Blockade

1. Background

The ongoing worldwide trend is to perform bariatric surgery as a short-stay procedure (1). The question thus is not whether bariatric surgery can be done as an outpatient procedure, but rather by whom and in what setting can patient outcome be optimized (2). For morbidly obese patients, the anesthetic approach focuses on choosing drugs that have the least potential for accumulation, allowing a more rapid and clear-headed recovery, and contributing to a reduced perioperative time (3, 4). However, when neuromuscular blockade (NMB) is required during surgery, complete recovery is a major concern and the return of NMB after a period of seemingly normal neuromuscular function (recurarization) is always a possibility that may prevent fast-track discharge (5).

NMB is frequently used in abdominal surgery to improve surgical conditions via relaxation of the abdominal muscles, preventing sudden muscle contractions that may cause serious complications, such as an instrument perforating a bowel or a large vessel (6). Studies are now evaluating the impact of NMB on laparoscopic surgical conditions, but none so far have evaluated the bariatric surgeon's satisfaction (7-9).

In Canada, NMB reversal is most commonly achieved by using acetylcholinesterase (AChE) inhibitors, usually neostigmine, which must be administered after a certain level of spontaneous recovery in order to ensure a complete reversal. This may lengthen the time spent in the operating room (OR), preventing a fast track surgical procedure. In the post-anesthesia care unit (PACU), postoperative residual curarization (PORC) may be particularly problematic due to the possibility of critical respiratory events (10). Although the incidence is low, PORC may lead to respiratory insufficiency, impaired upper airway function (11), and increased risk of aspiration (12). This, in turn, is also associated with significantly delayed discharges (13).

Because of the aforementioned inconveniences, Canadian anesthesiologists are reluctant to induce deep NMB (14). Consequently, intra-abdominal pressure remains non-optimal during the surgery, which complicates the surgeons' work, in addition to increasing perioperative time. This problem is particularly frequent in cases of bariatric surgery. Conversely, we know that muscle relaxation during laparoscopy for bariatric surgery helps to increase the abdominal volume and therefore the surgical visibility, certainly in a small abdomen (15).

This observational study aims to better assess the relationship between NMB and multiple surgical outcomes in patients undergoing elective laparoscopic sleeve gastrectomy (LSG). Duration of surgery, surgeon satisfaction, and quality of recovery in the PACU were all evaluated and correlated with NMB depth during surgery.

The current study explored this question from the perspective of surgeon satisfaction, and the patient's quality of recovery.

2. Methods

Between January and September 2015, a prospective study of 50 morbidly obese patients undergoing elective LSG under general anesthesia, at the Rockland MD ambulatory surgical center, was conducted. Approval from the Hôpital du Sacre-Cœur de Montreal ethics committee (October 2014), and informed written consent were obtained. Each participant was over 18 years of age. Participation in the project was offered to the patients eligible for ambulatory bariatric surgery; the first 50 patients who agreed were included in the study.

Rocuronium was used for tracheal intubation with bolus doses to maintain NMB throughout the surgery. At the end of the surgery, all patients received neostigmine 2.5 mg to reverse NMB. Criteria for exclusion were known or suspected disorders affecting NMB: a renal, pulmonary, cardiac, and/or hepatic dysfunction, malignant hyperthermia, pregnancy, breastfeeding, and allergy or contraindication to narcotics, rocuronium, neostigmine, or other medications used during anesthesia.

Given that this is an observational study on the surgical/anesthetic practice, with no predefined procedure, the surgeons and anesthetists both proceeded as per usual standard of care. Medications, doses, forms, and routes were all determined by the anesthetist, according to his clinical judgment. NMB was monitored at 5 minute intervals during the surgery, and at 30 second intervals following the reversal agent (neostigmine). For this purpose, acceleromyography (TOF-Watch® SX, Organon Inc., West Orange, NJ) was recorded at the adductor pollicis muscle starting just before rocuronium administration, and until tracheal extubation. Quantitative train-of-four (TOF) monitoring was used to quantify NMB depth.

During the laparoscopic procedure, the surgeon scored the surgical working conditions at 15 minutes intervals, according to a 5-point ordinal scale, and ranging from 1 (extremely poor conditions), 2 (poor conditions), 3 (acceptable conditions), 4 (good conditions) and 5 (optimal conditions) (16). This was our primary outcome. The surgeon was blinded to all anesthesia procedures, substances, or doses during these scoring periods. Demographic data (age, gender, BMI, comorbidities); perioperative data (time of surgery from first incision to last stitch, intra-abdominal pressure variations, perioperative complications) and postoperative complications were analysed. Quality of post-operative patient recovery will be based on symptoms felt (nausea and pain) as well as a quantitative evaluation of analgesic and antiemetic requirements.

2.1. Statistics

2.1.1. Data Analyses

Descriptive analyses were performed on all variables. A series of separate general linear model analyses were conducted with level of NMB (moderate vs. deep) as our independent variable, and all other perisurgical and anesthetic variables as the dependent variable. The main analyses were first conducted without statistical adjustment and then with the inclusion of age, sex, and BMI as a-priori defined covariates. For analyses, which included covariates, adjusted means and standard errors are reported. All analyses were conducted using SAS version 9.4 (SAS, NC, USA) with a $P < 0.05$ considered statistically significant. In addition to standard F-ratio and p-values, we also reported η^2 as a measure of effect size, i.e., amount of variance accounted for by NMB for each analysis.

3. Results

Forty-two females and 8 males, with a mean age of 38.8 years (range: 19 to 60, SD $\pm$ 9.2). Mean BMI for these patients was 43.9 (range: 36 to 58, SD: $\pm$ 5.1). All patients underwent day surgery with a mean time of 7,25 hours (range: 6 to 11) between arrival and departure from the center. There were no patient hospitalizations, readmissions, or surgical complications. Patients with comorbidities were also enrolled, and are described in Table 1.

During the surgery, 22% of patients were in intense or deep block (TOF count of 0, every 5 min.), and 78% were in moderate block (TOF count of 1 to 3), for the entire duration of the laparascopic procedure. All patients received a 50 or 70 mg induction dose of rocuronium. Among the

Table 1. Patient Characteristics[a]

Characteristics	Patients (N = 50)
Age, y	38.8 ± 9.2
Weight	285 ± 35.7
Body mass index, Kg/m^2	43.9 ± 5.1
ASA score	2.3 (1 - 3)
Female	42 (84)
Comorbidities	23 (46)
Hypertension	13 (26)
Type II diabetes	1 (2)
Sleep apnea	12 (24)
GERD	2 (4)
Hyperlipidemia	4 (8)
Length of stay, h	7.25 (6 - 11)
Overnight hospitalization	0
Readmission	0

[a]Values are expressed as mean ±standard deviation or mean and range.

patients with moderate block, 42 % required an additional dose of rocuronium during the surgery (range: 1 to 4 doses) for a mean dose of 12.8 mg (range: 5 to 20 mg). Only one patient in the deep block group received an additional dose (20 mg) as a matter of timing.

Information regarding the administration of propofol, fentanyl and morphine was gathered during procedures. For patients with deep NMB, only 1 out of 11 patients (9%) received 350 mg of propofol at induction, while the others had 200 mg of propofol. As for fentanyl, induction doses given were 250 mcg, except for 3 out of 11 patients who received 100 mcg or 200 mcg. Patients received either 15 or 0 mg of morphine at the time of induction. No additional dose of propofol or morphine had to be administered during the procedure. Only 2 patients out of 11 (18%) received one additional dose of fentanyl during the procedure. One patient received 100 mcg of fentanyl due to tachycardia, and 1 received 50 mcg for an unstated reason. The total average of fentanyl given throughout the procedure was 236.4 mcg and the median remained 250 mcg.

For patients with moderate NMB, propofol induction doses ranged from 200 to 300 mg and fentanyl induction doses ranged from 100 - 250 mcg. Patients received either 15 or 0 mg of morphine at the time of induction. The median administered was 200 mg for propofol, 250 mcg for fentanyl, and 0 mg for morphine. Only 1 patient out of 39 received an additional 100 mg of propofol, when the patient made a thoracoabdominal effort. No additional morphine dose was given during the procedure. As for fentanyl, 20 out of 39 patients (51%) received at least 1 additional dose of fentanyl ranging from 50 to 100 mcg at a time. Of the 20 patients who received additional doses of fentanyl, 1 had thoracoabdominal movements, 5 had tachycardia, and 3 had hypertension. Furthermore, 2 patients received an additional dose at the time of CO_2 insufflation, 1 at the time of the incisions, 2 during the insertion of the bougie, and 4 when the bougie was removed. For 2 out of 20 patients, no apparent reason was flagged.

During surgery, there was a modification in the work conditions for 6 patients: 4 with poor surgical conditions, and 2 where the procedure had to be interrupted and the instruments removed to wait for a return to acceptable conditions. Six patients had an increase in intra-abdominal pressure, among which there were 3 with deteriorating work conditions. All these patients required additional doses of rocuronium.

A sudden abdomen pressure increase during surgery was associated with a greater percentage of time at a TOF count of 4 (49% of the time), compared to a stable abdomen pressure (27% of the time), but this was not statistically significant (P = 0.15).

Eighty-three percent of the patients with poor or extremely poor (score of 1 or 2) surgical working conditions had a TOF count of 4, and 83% of patients with an increase in intra-abdominal pressure had a TOF count of 4. None of these patients were in deep block at that time. On average, an extra 1.7 doses (range: 0 to 4) of rocuronium was given to patients with modifications in their work conditions, as opposed to an average 0.39 doses (range: 0 to 2) for the 44 other patients, for whom conditions remained adequate during the surgical procedure. The anesthesiologist noted that 20 patients had respiratory or muscular movements during the surgery, but without repercussions on the surgeon's working conditions. Having poor or extremely poor surgical working conditions was associated with a greater percentage of time at a TOF count of 4, compared with good or optimal (score of 4 or 5) surgical working conditions (59% of the time VS 25% of the time, P = 0.011). Furthermore, there was a trend for patients in moderate NMB toward receiving additional doses of rocuronium more often during the case (P = 0.056). As shown in Table 2, adjustment for the a-priori defined covariates age, sex, and BMI showed similar results to the unadjusted models. None of the patients suffered from surgical complications during the procedure (Table 2).

Mean laparascopic time was 50 minutes (range: 25 to 113), and mean total surgical time was 63 minutes (range: 37 to 128). The amount of CO_2 gas used during the laparascopic period was of 84 liters (range: 37 to 233). Patients in deep NMB had a shorter laparoscopic time (37 minutes, SD

Table 2. Comparison of Deep VS Moderate NMB on Key Surgical Variables

Outcome M (SE)	Moderate NMB	Deep NMB	F	P Value	η^2 (95% CIs)
Laparoscopy time					
Unadjusted	53.0 (2.7)	36.8 (5.0)	8.15	0.006	0.15 (0.01 - 0.32)
Adjusted[a]	53.5 (2.8)	35.8 (5.2)	8.85	0.005	0.18 (0.00 - 0.32)
Total surgical time					
Unadjusted	66.6 (2.7)	49.8 (5.1)	8.62	0.005	0.15 (0.02 - 0.33)
Adjusted	67.2 (2.8)	48.6 (5.2)	9.95	0.003	0.21 (0.00 - 0.35)
Extra doses of blocker					
Unadjusted	0.67 (0.14)	0.09 (0.26)	3.84	0.056	0.07 (0.00 - 0.24)
Adjusted	0.69 (0.14)	0.06 (0.27)	4.24	0.045	0.09 (0.00 - 0.22)

[a] Data reported adjusting for age, sex, and BMI.

$\pm$ 7.1 vs 53 minutes, SD $\pm$ 18.3; P = 0.006).

In the post-anesthesia care unit (PACU), the average pain felt by patients, expressed on a scale from 1 to 10, was of 4.4 (range: 2 to 9). They received, on average, 13.9 mg (range: 5 to 52) of morphine equivalent. On the total of 50 recruited patients, 34% had no post-operative nausea, 50% had nausea controlled by anti-nausea drugs, and 16% suffered from nausea despite medication. There was no critical respiratory event in the PACU.

On average, women had more bouts of nausea (1.0) compared to men (0.14) (P = 0.004), and took more anti-nausea drug doses (1.24 vs 0.13; P = 0.006). Younger individuals took more anti-nausea drugs compared to older individuals (P = 0.015). A higher cumulative morphine dose was associated with a greater percentage of time at a TOF count of 4 (P = 0.079). No statistical differences were found between deep and moderate blockage for pain, morphine use, nausea, or anti-nausea medications (Table 3).

Table 3. Comparison of Deep VS Moderate NMB on Post-Operative Pain and Nausea

Mean (SD)	Moderate NMB	Deep NMB	P Value
Pain (1 to 10)	4.3 (1.9)	4.7 (2.3)	0.59
Equivalent Morphine Use, mg	13.6 (7.4)	14.9 (13.2)	0.66
Nausea (score 0 to 3)	0.84 (0.69)	0.82 (0.75)	0.94
Anti-nausea doses	1.15 (1.16)	0.73 (0.65)	0.25

4. Discussion

For close to a decade, ambulatory surgery for obese patients has proven to be valid and safe for bariatric surgery, regardless of the reluctance felt by many anesthesiologists because of the perioperative risks, especially pulmonary problems (4).

Morbid obesity (MO) is associated with important physiological and anthropometric changes that alter the pharmacokinetic properties of most drugs (17). Improved knowledge of the pharmacology of anesthetic drugs in this population, and a better collaboration between surgeons and anesthesiologists, favors the optimization of the general anesthesia protocol. We wanted this study to reflect actual anesthetic and surgical conditions, which is why it was performed without a specific anesthetic protocol, to avoid a standardization of the anesthetic approach. This explains why 22% of patients were in deep NMB while 78% were in moderate NMB. Seven different anesthesiologists were involved in the 50 patients' anesthesia.

Rocuronium was used for tracheal intubation and to maintain NMB throughout the surgery, in all 50 patients, which is common practice here and not because of a standardized protocol. Our patient cohort reflects the worldwide trend favoring the sleeve gastrectomy, currently the most popular bariatric procedure in North America (18). Women consult much more than men for bariatric surgery, which explains why the majority of our study population is female. Close to half the patients suffer from obesity related diseases, however, only 2% of the patients from our series were diabetic. Indeed, since the inception of our ambulatory surgery program we have excluded insulin-dependant patients, to eliminate the risk of high fluctuation in glycemic levels postoperatively without medical supervision.

This study demonstrates once again the feasibility of ambulatory surgery, without an overnight stay or hospitalization. Because the average length of stay is 7.25 hours (range: 6 to 11), no surgical intervention began after 12:00

PM, to ensure that the patient could return home in the early evening. None of the patients required a transfer to the hospital, or readmission for a complication.

The results of this study confirmed that deep NMB decreases the incidence of unacceptable surgical conditions. Although excellent operating conditions were frequently obtained without deep NMB, maintaining deep NMB significantly improved surgical conditions by completely preventing abdominal wall muscle contractions. No patient with deep NMB had poor or extremely poor surgical working conditions, nor any intra-abdominal pressure modification. The only patient with a poor/ extremely poor, surgical working condition, without a TOF count of 4, was a difficult case with a BMI of 50, associated to gastric band removal 6 months previously. The TOF count was 1 and 2 during the case.

These results were expected because complete relaxation of the abdominal wall, and the absence of involuntary patient movements, improves the operative field and prevents any untoward movement during the surgical procedure. These involuntary movements can occasionally cause iatrogenic complications during the case, which did not occur during our study. Morbidly obese patients already represent a technical challenge in laparoscopy, because of the amount of fat present in their abdominal cavity, limiting the visual field. Although the difference is not statistically significant ($P = 0.15$), there was a trend toward more sudden intra-abdominal pressure increases in patients with a TOF count of 4.

Comparing the two groups, it appears that they received similar doses of propofol, fentanyl and morphine at the time of induction. It is interesting to note that patients who were in deep NMB received less fentanyl throughout the procedure. Propofol and morphine were not administered during the procedure, except for a single dose of 100 mg of propofol given to a patient in moderate NMB, experiencing thoracoabdominal efforts. More than half the patients received at least 1 additional dose of fentanyl during the procedure, ranging from 50 to 100 mcg per dose for patients who were in moderate NMB. This can be attributed to several factors such as thoracoabdominal movement, tachycardia, hypertension, CO_2 insufflation timing, incision timing, and insertion or removal of the bougie. It appears that patients who were in deep NMB did not have enough adverse reactions for the anaesthetist to administer additional doses of the aforementioned medications. As opposed to Carron et al. (19), our study clearly shows a reduction of operative time (laparascopic and total). This can be attributed to the 6 patients with moderate NMB, with bad working conditions. All 6 required additional doses of rocunorium while the surgeon had to wait for a return to acceptable working conditions. In 2 patients, the laparascopic instruments had to be removed to prevent any iatrogenic laceration.

However, this could also be attributed to the fact that an easier or faster surgery is possible with the patient in deep NMB. The longer the surgery, the greater the chance that the patient will be in moderate NMB. This would also explain that the moderate NMB group had to receive more complementary doses of medications, due to a longer procedure. The only way to answer this question would be to carry out a randomized study comparing a group where all patients are in deep NMB, with another group in moderate NMB.

Furthermore, it has been clearly demonstrated that optimal and safe doses of curare are difficult to estimate in patients with morbid obesity. This probably explains, in part, why some patients underwent the entire surgery in deep NMB while others were in moderate NMB (20).

The subjective evaluation of the pain or nausea felt by patients showed no significant difference between the two groups. Pain, morphine equivalent doses, and nausea were similar for both groups. Only the anti-nausea usage favored the deep NMB group ($P = 0.25$). However, we noted a trend in patients who spent a higher percentage of time in TOF count of 4, to use more morphine equivalent doses ($P = 0.079$). We have clearly shown that female patients have more nausea ($P = 0.004$), and consume more anti-nausea drugs ($P = 0.006$), as do the younger patients ($P = 0.015$). This does not appear to have influenced the comparison between the 2 groups since we had 82% of female in the moderate NMB group with a mean age of 38.1 years, compared to 91% and 41.5 years for the deep NMB group. More patients would be needed in the deep NMB group to see a significant statistical difference on the impact of deep curarization on postoperative pain or nausea.

This study has several limitations, being observational, without a pre-established protocol and on a limited number of patients (50). Furthermore, it focuses exclusively on surgeon satisfaction regardless of the anesthetic technique used.

In conclusion, ambulatory surgery's increasing popularity requires that patient safety remains paramount, but an optimal use of resources is also key. This study shows that deep NMB prevents any untimely abdominal wall movement, and consequently, makes the surgery safer.

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