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# Quantitative Versus Qualitative Monitoring of Neuromuscular Blockade in Morbidly Obese Patients Undergoing Bariatric Surgery: Differences in Residual Neuromuscular Block and Respiratory Complications

**Patrick Ziemann-Gimmel[1*], Allison A. Goldfarb[1], Meghan Connelly[1], Ahmed Bata[1], Robert Marema[2], Dmitry Tumin[3]**

[1]Department of Anesthesiology, Envision Healthcare Inc, Plantation, USA

[2]Department of Surgery, Flagler Hospital, St Augustine, USA

[3]Center for Epidemiology of Organ Failure and Transplantation, Nationwide Children's Hospital, Columbus, USA

[*]**Corresponding author:** Patrick Ziemann-Gimmel, 400 Health Park Boulevard, St Augustine, FL 32086, USA. Tel: +19042380131; Email: pziemann@yahoo.com

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## Abstract

**Background:** Morbidly obese patients are at high risk of developing respiratory complications in the post-operative period following bariatric surgery. The literature suggests that quantitative management of neuromuscular blockade reduces the residual weakness which leads to critical respiratory events in the post-operative period. Thus, we investigated which approach, qualitative or quantitative monitoring of neuromuscular blockade left patients with a degree of residual neuromuscular block that created a greater risk of having critical respiratory events.

**Methods:** Morbidly obese patients undergoing bariatric operations were enrolled in a prospective randomized parallel-group single-center trial. In the control group administration of the reversal agent neostigmine and tracheal extubation was based on qualitative monitoring of neuromuscular blockade whereas in the intervention group it was based on quantitative measurements via acceleromyography.

**Results:** By study design there was no difference in the intraoperative dosing of intermediate neuromuscular blocking agents. The control group showed a mild degree of residual neuromuscular block relative to the intervention group at the time of extubation (TOF ratio mean 0.86 versus 0.94). There was no difference in the occurrence of critical respiratory events in the post-anesthesia care unit. After 317 of the 362 patients were enrolled sugammadex was added as a reversal agent at the study facility. As a result, the study was terminated early. A futility analysis indicated that the study had less than 1% conditional power for rejecting the null hypothesis if the target enrollment had been achieved.

**Conclusion:** Quantitative monitoring of neuromuscular blockade reduced the amount of residual neuromuscular blockade at the time of extubation. However, it did not decrease the risk of critical respiratory events.

**Keywords:** Monitoring; Morbid; Neuromuscular; Obesity; Qualitative; Quantitative

## Introduction

### Background

Several studies have identified Chronic Obstructive Pulmonary Disease (COPD), long surgery, old age, high *American Society of Anesthesiologists* (ASA) score, a history of congestive heart failure, emergency surgery and functional dependence as main risk factors triggering post-operative pulmonary complications [1,2]. Qualitative relative to quantitative management of neuromuscular blockade predisposes patients to post-operative residual neuromuscular block [3]. Post-operative residual neuromuscular block seems to be a risk factor for post-operative pulmonary complications and critical respiratory events [4]. Moreover, morbidly obese patients are at risk for post-operative respiratory events [5].

### Rationale/significance

Our current clinical practice of monitoring neuromuscular blockade uses a standard peripheral nerve stimulator to stimulate the facial nerve (qualitative) and visually assess the response of the Corrugator Supercilii Muscle (CS). The CS is more resistant to the effect of neuromuscular blocking agents, requires higher concentrations / doses, and leaves patients with a considerably high degree of post-operative residual neuromuscular block [6,7]. It is recommended to use quantitative monitoring at the Adductor Pollicis Muscle (AP) to avoid post-operative residual neuromuscular block [8].

### Study objectives/aims

The aim of the study was to determine whether the risk of post-operative residual neuromuscular block and respiratory complications could be decreased by using quantitative neuromuscular monitoring (Acceleromyography [AMG]) compared to our current clinical practice, using qualitative (visual) neuromuscular monitoring. We hypothesized that patients in the control group using qualitative (visual) assessment have a higher incidence of respiratory complications than patients in the study group using AMG of the AP.

## Materials and Methods

### Trial design

This prospective, randomized parallel-group single-center study was conducted at Flagler Hospital, St Augustine, FL, USA. The study complied with the Declaration of Helsinki and was approved by the local Institutional Review Board (Flagler Life Institute, St Augustine, FL, USA, #00006886. All participating patients gave written consent. The study was registered at clinicaltrials.gov NCT02037516 (https://clinicaltrials.gov/ct2/show/NCT02037516).

### Participants

Patients were considered eligible and screened for inclusion if they were older than 18 years, with a Body Mass Index (BMI) greater than 35 kg $m^{-2,}$ undergoing elective bariatric surgery including laparoscopic Roux-en-Y gastric bypass (including revision and conversion), sleeve gastrectomy and laparoscopic Roux-en-Y gastric bypass with another procedure (e.g. hiatal hernia repair) at Flagler Hospital from January 2014 to January 2016. Patients with pre-existing neuromuscular disease or known allergies to any medication used in the study were excluded (Figure 1).

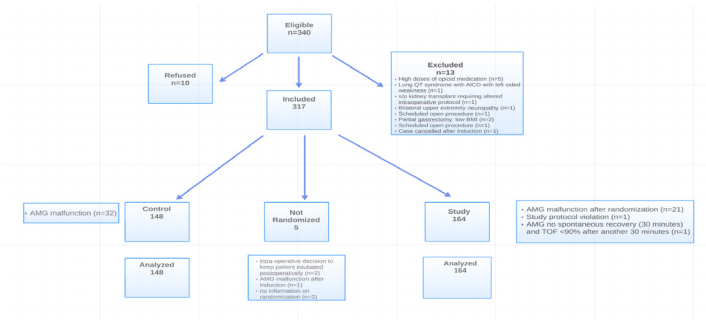


**Figure 1:** Patient flow diagram.

- After written informed consent was obtained, patients were sedated with midazolam 2 mg - 4 mg intravenous (iv) and transported to the operating room. Standard monitors and the AMG were applied. A loading dose of dexmedetomidine (0.5 - 1 mcg $kg^{-1}$) infused over 10 minutes was started. After preoxygenation, general anesthesia was induced with a bolus of propofol (1 - 2.5 mg $kg^{-1}$). After mask ventilation was established, the AMG was calibrated, and a neuromuscular blocking agent was administered (rocuronium, vecuronium or succinylcholine). The choice and dose of Neuromuscular Blocking Agent (NMBA) was left to the anesthesia provider's discretion. Succinylcholine was only used to facilitate tracheal intubation and not for maintenance of neuromuscular blockade. General anesthesia was maintained with an infusion of propofol (75 - 200 mcg $kg^{-1}$ $min^{-1}$) and dexmedetomidine (0.1 - 0.3 mcg $kg^{-1}$). Perioperative analgesia was provided by ketamine (0.5 mg $kg^{-1}$), paracetamol (1000 mg) and ketorolac (30 mg) iv.
- Intraoperative administration of neuromuscular blocking agent was guided by qualitative assessment of the Corrugator Supercilii Muscle (CS). At the end of the operation, patients were randomized (see paragraph "Randomization") to the QuaL or QuanT group for extubation purposes.
- In the QuaL group the administration of the reversal agent

neostigmine and tracheal extubation were guided by qualitative assessment of the CS.

- In the QuanT group administration of reversal agent and tracheal extubation were guided by AMG of the Adductor Pollicis Muscle (AP). Neostigmine was administered after a spontaneous recovery to at least three twitches of the AP and the patient's trachea was extubated once the TOF ratio ≥ 0.9.

It was quickly discovered after enrolling 23 patients (QuaL = 11 and QuanT = 12) that administration of neostigmine after spontaneous recovery to three twitches on the AMG of the AP before administration of neostigmine was insufficient to reliably reach a TOF ratio ≥0.9 in morbidly obese patients. The majority of patients in the Quant group did not reach a TOF ratio of 0.9 even after waiting for 30 minutes after administration of neostigmine. This prompted a change in the protocol. Morbidly obese patients had to show a spontaneous recovery of at least 4 twitches of the AP or a TOF ratio before the administration of neostigmine was permitted. The protocol in the QuaL group was not changed due to the hypothesis testing: comparing our current clinical practice using qualitative management, where we allow reversal to be administered after a TOF≥3 is observed at the CS, to the QuanT group. After the patient's trachea was extubated, supplemental oxygen was delivered and the patient transported to The Post-Anesthesia Care Unit (PACU). The nurses assessed patients for respiratory symptoms documented interventions (Appendix A) and recorded the time when the patient fulfilled discharge criteria. Hydromorphone iv (0.5 - 1.0 mg) was administered as first line therapy for post-operative analgesia. After discharge to the ward, post-operative multimodal pain management was used. [11] Paracetamol and ketorolac were given every six hours iv for the first 24 hours. For mild breakthrough pain oral oxycodone (5 - 10 mg) or, for severe pain, iv hydromorphone (0.5 - 1.0 mg) were administered.

## Initial Setup

For quantitative monitoring of neuromuscular blockade, AMG (TOF-watch SX, Biometer, Denmark) was used. The transducer was attached to distal volar site of the thumb. The electrodes were placed above the ulnar nerve with a distance between the electrodes of 3 - 5 cm. The hand was then covered with the sleeve of a forced air warming upper body blanket ensuring the thumb was able to move freely. TOF-Watch data were transferred to a computer. General anesthesia was induced, and the TOF-Watch Was Calibrated (CAL2) to ensure supramaximal stimulation and adjustment of the sensitivity prior to administration of any neuromuscular blocking agent. If calibration was not performed (e.g. due to rapid-sequence induction, anticipated difficult airway, rapid desaturation, or parallel surgical procedures and unavailability of second TOF-Watch), the current was set at 60 mA (default machine setting is 50 mA). TOF stimulation was done every 15 seconds (background) and data recorded for analysis until tracheal extubation. TOF watch display, as well as the movement of the thumb, was blinded to the anesthesia provider until randomization.

## Randomization

During the operation, anesthesia providers were blinded to the results of AMG monitoring (see "Initial Setup"). Patients were randomized towards the end of the surgery (trochar removal). Based on the surgical progress and the qualitative assessment measurement of a TOF ≥ 3, reversal could be given at this time point ("ready to reverse"). At this time the anesthesia provider called one of the investigators who randomized the patient using www.random.org or R. The anesthesia provider was notified of the group randomization (QuanT/QuaL). The choice of this specific time points for randomization avoided intraoperative dosing adjustments of NMBAs based on group randomization. Providers remained blinded to their group, so as to not impact neuromuscular blocker management during the case. All dosing of NMBAs was based on qualitative assessment or surgeon request. Reversal could not be given until after group randomization.

The anesthesia providers were blinded until randomization at the end of the procedure. If a patient was randomized to the QuaL group, the anesthesia provider remained blinded to the AMG. If the patient was randomized to the QuanT group, the AMG was uncovered and used to guide the anesthesia provider in the administration of neostigmine. The PACU nurses and respiratory therapists were blinded throughout the study period. Data entry was performed by blinded investigators. As per protocol, unblinding was allowed in the perioperative period to allow treatment of any emergencies requiring intervention.

## Definition of endpoints / respiratory symptoms and interventions

The primary endpoint in the current study was the incidence of patients developing a respiratory symptom or complication. For the definition of respiratory symptom or complication, please see (Appendix A). The secondary endpoints were comparison of oxygen flows, oxygen devices, post-operative respiratory complications, the incidence of post-operative residual neuromuscular block defined as a TOF ratio < 0.9 and spirometry values in the post-operative period. Post-operative respiratory complications were defined as any new respiratory treatment or hospitalization for suspected or confirmed respiratory infection. Patients were followed either by phone interview, chart review or at the post-operative visit at 2 and at 4 weeks (Appendix B). A subgroup analysis of respiratory complications was not planned. A subgroup analysis on patients with a TOF ratio < 0.9 was not planned. A Respiratory Therapist

(RT) assessed and examined the patient in the preoperative period. Patients were instructed to use incentive spirometry and baseline data were recorded.

## Statistical Analysis

The data were entered in an Excel spreadsheet and later transferred to SPSS and Stata/IC 13.1 (College Station, TX: Stata Corp, LP) for analysis. All analyses grouped patients according to the intent-to-treat group assignment. The categorical data were analyzed with the $\chi^2$ test for independence or the Fisher exact test. The quantitative data were analyzed using the unpaired Student t-test for significance. If data were not normally distributed as assessed by the Shapiro-Wilk test, the Wilcoxon rank-sum test was used. Ordinal data were analyzed using the Wilcoxon rank-sum test. Highly skewed quantitative data were presented as median with Interquartile Range (IQR). Spearman correlations of ranks were used to test for trends in intraoperative characteristics over the interval of study months.

Repeated-measures data on post-operative respiratory interventions, requirement for supplemental oxygen, and presence of abnormal breath sounds were dichotomized and compared between groups using $\chi^2$ tests. Repeated-measures data on incentive spirometry performance were analyzed using multivariable mixed-effects regression with a patient-level random intercept. Incentive spirometry values over the duration of hospitalization were modeled as a quadratic function of time since the earliest post-operative measurement, and were adjusted for patient age, BMI, liposomal bupivacaine use, surgical time, and preoperative abnormal findings on auscultation. Intervention group differences in incentive spirometry were first assessed by introducing group assignment to the model as an intercept shift, and secondarily by interacting group assignment with the parameters of the quadratic time function. Concordance of independently evaluated AMG tracings between the investigators was confirmed using Lin's concordance correlation coefficient. A stochastic curtailment analysis of futility for a two-sided test of 2 proportions was performed, assessing the likelihood of detecting the hypothesized difference in respiratory complications between the 2 groups if study enrollment had been completed as planned.

Power analysis for a z test, difference of two independent proportions indicated that a total sample size of 362 is adequate (alpha = 0.05, beta = 0.2, p1 = 0.3, p2 = 0.175; G*Power 3). An incidence of 30% of a respiratory complication was chosen because the definition of respiratory events in the current study was more comprehensive and the observation period longer than the one used to detect an incidence of 25% in our institution [5]. We maintain that an absolute risk reduction of 12.5% was clinically relevant. The study was terminated early after enrollment of 317 patients. A futility analysis was performed to determine the conditional power rejecting the null hypothesis.

## Results

Patient enrollment is shown in (Figure 1). Three hundred and seventeen patients gave written consent and were included in the study. There were 5 patients not randomized and those results have not been included in the analysis (see Figure 1). The reasons to not randomize patients or not include patients in the analysis: intraoperative decision to keep patients' trachea intubated (n = 2), AMG malfunction (n = 1) and missing information on randomization (n=2). Baseline characteristics are presented in (Table 1).

| | unit | QuaL (n=148) | QuanT (n=164) |
|---|---|---|---|
| Age | years | 50 (1.9)* | 49 (2.0)* |
| Gender | m/f (%) | 44/104 (30 / 70) | 41/123 (25 / 75) |
| Height | cm | 169 (1.6)* | 167 (1.5)* |
| Weight | kg | 128 (4.5)* | 127 (4.6)* |
| BMI | $kg/m^2$ | 45 (1.2)* | 46 (1.4)* |
| LOS | days | 2 [1;2]$ | 2 [1;2]$ |
| LB | yes/no (%) | 47/101 (32 / 68) | 63/101 (38/ 62) |
| Morbidity Risk Score | none | 2 [2;3]$ | 2 [2;3]$ |
| Mortality Risk Score# | none | 3 [2;3]$ | 2 [2;3]$ |
| ASA Score | none | 3 [3;3]$ | 3 [3;3]$ |

QuaL: dosing of neostigmine reversal based on qualitative monitoring of the corrugator cilii muscle, QuanT: dosing neostigmine reversal based on quantitative monitoring of the adductor pollicis muscle, BMI: body-mass-index, LOS: length of stay, LB: liposomal bupivacaine, *: mean (SD),$: median [interquartile range]; NMBA: 63.4% patients received rocuronium, 28.4% received vecuronium and 8.2% received both.

**Table 1:** Baseline characteristics and risk scores.

### Intraoperative

63.4% of patients received rocuronium, 28.4% received vecuronium and 8.2% received both. There was no difference in the total doses of NMBAs or neostigmine. The time interval from last dose of NMBA to reversal was longer by approximately 8 minutes in the QuanT group relative to the QuaL group (Table 2).

| | units | QuaL (n=148) | QuanT (n=164) | p |
|---|---|---|---|---|
| Vecuronium | mg | 12.4 (1.4)* | 14.1 (1.4)* | 0.07 |
| Rocuronium | mg | 87.1 (6.1)* | 85.0 (6.0)* | 0.63 |
| LD any NMBA to reversal | minutes | 35.2 (2.5)* | 43.7 (3.4)* | < 0.001 |
| Neostigmine | mg | 4.7 (0.1)* | 4.8 (0.1)* | 0.70 |
| TOF at time of reversal | % | 9.9 (2.7)* | 16.1 (3.1)* | 0.005 |
| TOF at time of extubation | % | 85.8 (3.2)* | 93.9 (2.0)* | < 0.001 |
| Reversal to extubation | min | 13.9 (1.3)* | 19.2 (1.7)* | < 0.001 |
| In OR to intubation | minutes | 14.3 (0.7)* | 14.9 (0.8)* | 0.24 |
| Intubation to incision | minutes | 30.4 (1.3)* | 31.6 (1.4)* | 0.22 |
| Surgical time | minutes | 112.0 (8.8)* | 106.5 (6.5)* | 0.31 |
| Surgical end to extubation | minutes | 10.0 (2.2)* | 21.7 (3.5)* | < 0.001 |
| Surgical end to PACU | minutes | 19.2 (2.7)* | 29.1 (3.4)* | < 0.001 |
| Extubation to PACU | minutes | 8.9 (1.7)* | 8.5 (0.6)* | 0.65 |
| PACU ready for discharge | minutes | 63.3 (4.6)* | 64.7 (3.7)* | 0.64 |

QuaL: dosing of neostigmine reversal based on qualitative monitoring of the corrugator cilii muscle,QuanT: dosing neostigmine reversal based on quantitative monitoring of the adductor pollicis muscle,LD: last dose,OR: operating room, PACU: post-anesthesia care unit,*: mean (SD)

**Table 2:** Intraoperative doses of Neuromuscular Blocking Agents (NMBA), Train-Of-Four Ratio (TOF) and intraoperative times.

TOF at the time of reversal and at the time of extubation was significantly lower in the QuaL group relative to the QuanT group (Table 3).

| Respiratory complications | unit | QuaL (n=148) | QuanT (n=164) | 95% Confidence interval | p |
|---|---|---|---|---|---|
| In PACU yes/no | n (%) | 45 / 103 (31 / 69) | 52 / 112 (31 / 68) | -0.21 | 0.88 |
| Within the first 2 weeks (yes/no) | n (%) | 11 / 137 (7 / 93) | 9 / 155 (6 / 94) | -0.04 – 0.08 | 0.49 |
| 2-4 weeks yes/no | n (%) | 4 / 142 (3 / 97) | 10 / 154 (6 / 94) | -0.02 – 0.09 | 0.15 |
| 0-4 weeks yes/no | n (%) | 13 / 135 (9 / 91) | 17 / 147 (10 / 90) | -0.06 – 0.09 | 0.62 |

QuaL: dosing of neostigmine reversal based on qualitative monitoring of the corrugator supercilii muscle,QuanT: dosing neostigmine reversal based on quantitative monitoring of the adductor pollicis muscle,PACU: post-anesthesia care unit.

**Table 3:** Critical respiratory events and post-operative pulmonary complications.

The Lin's concordance correlation coefficient demonstrated strong agreement of the TOF ratio between the two investigators at the time of reversal ($\rho_C = 0.70$, $p < 0.001$) and at the time of extubation ($\rho_C = 0.92$, $p < 0.001$). Furthermore, the time after reversal to extubation was significantly shorter in the QuaL group compared to the QuanT group. This extends the time from surgical end to extubation to a similar degree (Table 2). There were no statistically significant trends in the timing or dose of NMBA used over the 2-year study period. More patients in the QuaL group had post-operative residual neuromuscular block compared to the QuanT group, TOF ratio 0.537 versus 0.231 respectively ($p < 0.001$).

### PACU

Hemoglobin oxygen saturation, oxygen flow and device did not differ on PACU arrival. On PACU discharge patients in the QuanT group required a higher flow of oxygen with similar oxygen saturation using nasal cannula (Table 2). There was no difference in the number of patients having respiratory complication ($p = 0.88$) (Table 3).

### Post-operative

There was no difference in the number of patients requiring treatment from RTs (QuanT: 13%; QuaL: 14%) or requiring an oxygen device (QuanT: 58%; QuaL: 68%) in the post-operative period. The lowest hemoglobin oxygen saturation was similar in both groups (QuanT: 96 ± 2; QuaL: 96 ± 2). There was also no difference in patients having abnormal findings on auscultation (QuanT: 76%; QuaL: 74%). Mixed-effects regression of spirometry values over the initial (40 hour) post-operative period found no difference in this outcome between QuanT and QuaL when group assignment was considered to have an equal effect on spirometry at each time point (intercept shift of 83 mL; 95% CI: -121, 287; $p = 0.425$). Model predictions of spirometry values for QuanT and QuaL are shown in (Figure 2).

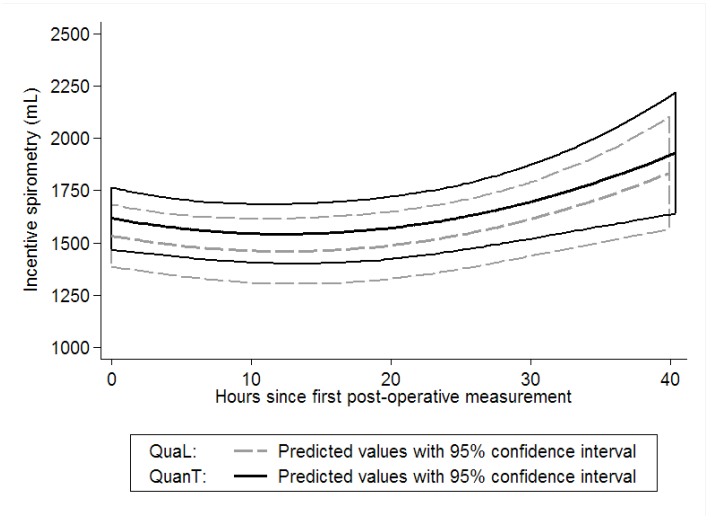


**Figure 2:** Values incentive spirometry.

Further analysis found that group assignment did not significantly modify the shape of the spirometry trajectory over the first 2 days of hospitalization. There was also no difference in the number of patients suffering from a respiratory complication in the first 4 weeks after hospital discharge at any time point ($p = 0.62$) (Table 3).

Due to early termination of the study, a futility analysis was performed to assess the likelihood of detecting the hypothesized difference in respiratory complications between the two groups, if study enrollment had been completed as planned. Given the observed data and expected effect size, the study had less than 1% conditional power for rejecting the null hypothesis if the target enrollment would have been achieved.

## Discussion

Qualitative management of neuromuscular blockade leaves morbidly obese patients undergoing bariatric surgery with a mild

degree of residual neuromuscular block. This does not increase the risk of developing a respiratory complication in the post-operative period.

There are several possible reasons for not detecting a difference in respiratory complications between groups. First, there was only a small degree of difference in residual neuromuscular block in the QuaL group compared to the QuanT group. The current recommendation based on expert opinion is to extubate the patient's trachea after TOFr > 0.90 measured quantitatively at the adductor pollicis [3]. In previous studies patients who developed a respiratory complication had a lower TOF ratio compared to the current study. In a case-control study where 2/3 of the patients could be matched to controls, respiratory complications (hypoxemia and upper airway obstruction) were more common in patients with post-operative residual neuromuscular block compared to controls (TOF 0.62 versus 0.98) [9]. In a prospective trial, mild hypoxemia ($SaO_2$ 90% - 93%) and swallowing difficulties were more common in patients with post-operative residual neuromuscular block (TOF 0.7 versus 1.0) [10]. In the current study, however, patients in the QuaL group had only a mild degree of residual block compared to the QuanT group (TOFr 0.86 versus 0.94). It is worth mentioning that AMG measurements suffer from frequent technical problems and are in uncooperative patients fairly unreliable during emergence from anesthesia [11]. The patients remained unconscious (motionless) under propofol anesthesia in the QuanT group, until several, reliable TOF measurements > 90% were achieved. Still, a total of 53 (16.9%) TOF-watch tracings could not be analyzed due to technical problems. In QuanT group 21 (12.9%) patients had to be reversed and extubated based on the qualitative method of monitoring neuromuscular blockade. Data were analyzed using the intention-to-treat method and these patients remained in the QuanT group.

Another reason for not detecting a difference of respiratory complications could have been the exclusive use of intermediate NMBAs. In a prospective randomized trial, residual neuromuscular block from intraoperative pancuronium use increased the risk of developing a Post-Operative Pulmonary Complication (POPC). Residual neuromuscular block in patients treated with intermediate acting NMBA (vecuronium/atracurium) did not show an increased risk of POPC [4]. In data mining studies [12,13] high doses of NMBAs and neostigmine were associated with an increase in respiratory complications. Data mining has its limitations [14] and in the current prospective randomized trial equal doses of intermediate acting NMBAs (vecuronium and rocuronium) and neostigmine were used in both groups.

Furthermore, the longer time of tracheal intubation and ventilation in the QuanT group and the use of supplemental oxygen could have reduced the difference of respiratory complications between groups. In a prospective study by Sauer et al. residual block increased the risk of mild hypoxemia (90% - 93%), but did not affect the risk of severe hypoxemia (< 90%) [10]. Oxygen is used routinely for transport in our institution. During the hospital stay, oxygen saturations were similar in both groups. In the QuanT group patients were intubated and ventilated longer compared to the QuaL group. This could have, theoretically, increased the severity of pulmonary atelectasis, elevating oxygen needs in the QuanT group.

During the study planning we expected to find a lower TOF ratio, more patients with post-operative residual neuromuscular block or more respiratory complications in the QuaL group compared to the QuanT group for mainly two reasons: (i) first, morbidly obese patients are considered a high-risk patient population, and (ii) second, the method / location of monitoring the degree of paralysis.

Morbidly obese patients are at high risk for respiratory events [5] and atelectasis [15] after bariatric surgery. Previous studies excluded morbidly obese patients [4,10]. In the study by Murphy et al., patients underwent a variety of different surgical procedures and had a BMI of approximately 30 kg $m^{-2}$ [9]. In our study, all morbidly obese patients (BMI ≈ 45 kg $m^{-2}$) underwent bariatric (upper abdominal) operations.

Quantitative (AMG) compared to qualitative methods of monitoring have been shown to be superior in detecting recovery from neuromuscular blockade at the end of operation. Qualitative methods frequently fail to detect TOF > 0.41 [16]. In the QuaL group, the CS was used to monitor the degree of neuromuscular blockade. The CS is more resistant to the effect of NMBA than the AP [17]. Therefore, using a method (qualitative) that is imprecise to detect recovery from neuromuscular blockade and more resistant muscle group (CS) to the effect of NMBAs should have left patients with a higher degree of post-operative residual neuromuscular block - a greater degree of block at other muscles including respiratory.

A limitation of the current study is the early termination. It was terminated because sugammadex became available at our institution. The investigators felt it would be unethical to withhold a superior drug from study participants. An insufficient number of patients were enrolled according to the power analysis during study planning. However, futility analysis indicated less than 1% conditional probability of rejecting the null hypothesis for the primary outcome if the intended number (n = 362) of patients had been enrolled. Another limitation affecting the validity of the current study is that the protocol had to be changed in the QuanT group. The protocol allowed reversal to be administered in the QuanT as soon as at least 3 twitches of the TOF were detected on the AMG at the AP. Morbidly obese patients enrolled in the study that received neostigmine at a TOF of 3 twitches did not reliably

recovered to a TOF ratio of > 0.9. The decision was made to delay administration of neostigmine until a TOF of 4 twitches or a TOF ratio was detected.

In conclusion, qualitative compared to quantitative management of neuromuscular blockade in morbidly obese patients during bariatric surgery leads to a mild degree of post-operative residual neuromuscular block. This mild degree of post-operative residual neuromuscular block does not seem to increase the risk for a critical respiratory events or post-operative pulmonary complications.

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