

Optimizing neuromuscular blockade management for improving patient safety and peri-operative outcomes: a pilot phase of a quality improvement initiative

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Abstract

Background: Although quantitative monitoring of neuromuscular blockade (NMB) is recommended, it is not routinely used in daily practice. The optimizing NMB management to improve patient safety and perioperative outcomes (OBISPO) quality improvement (QI) initiative intends to address this issue and change clinicians' behaviors.

Methods: A pilot phase of the prospective QI intervention was conducted. The primary objective was implement clinical practice change that emphasizes improving NMB monitoring in patients undergoing elective cardiac surgery who are eligible for fast-track extubation between February 2021 and December 2021. The secondary objective was to reduce the train-of-four ratio (TOFR) < 0.9 incidence before tracheal extubation to less than 20%. The intervention included educational sessions for teams.

Results: A total of 859 patients underwent elective cardiac surgery, 40% were eligible for fast-track extubation. From our cohort of fast-track cardiac cases, 69% had reported TOFR; 47% of them had residual paralysis (TOFR < 0.9) on arrival to PACU, 22% persisted with residual paralysis after extubation, and 27% were extubated without monitoring. The survey identified cognitive biases, knowledge gaps, unfamiliarity, and lack of trust in quantitative monitoring devices. Workflow disruptions imposed by COVID and changes in NMB monitoring devices have negatively affected our initiative.

Conclusions: Our study showed that changes in clinician behavior are among the most challenging issues in perioperative medicine. Continuous teaching and QI initiatives, focused on quantitative NMB monitors and adequate reversal agent use, are mandatory to improve perioperative outcomes. Therefore, new proposals are required to promote changes in current practices.

Key words: quality improvement, patient safety, residual neuromuscular blockade, quantitative NMB monitor, fast-track cardiac surgery.

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Residual neuromuscular blockade (NMB) following general anaesthesia is associated with a prolonged length of stay (LOS) in the post-anaesthesia care unit (PACU) [1], unscheduled critical care admission [2], hospital readmissions [3], and postoperative pulmonary complications [4, 5]. Routine monitoring of NMB reversal with train-of-four-ratio (TOFR) ensuring a value > 0.9 prior to extubation may reduce the incidence of postoperative pulmonary complications [6]. Despite evidence and professional guidelines mandating quantitative neuromuscular monitoring [7], clinical practice relies on clinical judgment and subjective assessments to determine the appropriateness of extubation [8].

This practice continues even though clinical tests such as head lift, grip strength, or spontaneous tidal volume are proven insufficient for ruling out residual paralysis [3–5].

To address the gap between standards and actual clinical practice, we undertook the Optimizing neuromuscular Blockade management for Improving patient Safety and Perioperative Outcomes (OBISPO) initiative. The primary goal was implementing clinical practice change emphasizing improved monitoring practices, ultimately reducing residual NMB. Our proposed two-phase quality improvement (QI) project focused on establishing a standardized NMB monitoring and



FIGURE 1. NMT Electron Sensor (GE HealthCare, United States)

pharmacological reversal strategy in the PACU and extending the change in care to the operating room (OR).

The initial phase of OBISPO, implemented in the PACU, primarily aimed to introduce a clinical practice change (clinician behaviour) by routine quantitative NMB monitoring. The secondary objective was to reduce residual NMB, defined as a TOFR of less than 0.9, in patients scheduled for fast-track extubation after elective cardiac surgery.

METHODS

This QI project included a cohort of all adult patients (aged ≥ 18 years) who underwent elective cardiac surgery and qualified for fast-track extubation at Toronto General Hospital PACU between February 1, 2021, and December 31, 2021. Approval for this study was obtained from the Institutional Research Ethics Board (UHN-REB), which operates in accordance with the Tri-Council Policy Statement of Canada and the International Conference on Harmonization-Good Clinical Practice Guidelines. The need for informed consent was waived by the REB given the QI nature of the project.

The primary outcome was assessed by evaluating the fidelity of implementation using run charts. The target was to record TOFR in at least 70% of the baseline cohort. Our secondary objective was to reduce residual NMB incidence before tracheal extubation to below 20% after the pilot phase.

An interdisciplinary QI team of staff anesthesiologists, fellows, residents, and PACU nurses was trained to implement and monitor practice changes. A series of Plan-Do-Study-Act (PDSA) cycles were conducted quarterly for root cause analysis, process mapping, evaluation of baseline data (1st quarter), development of improvement strategies (2nd quarter), education and feedback (3rd quarter), and overall assessment of practice change implementation (4th quarter).

Measures

Three types of measures were employed in this study:

Outcome measure: The primary outcome was the incidence of residual paralysis on PACU arrival, defined as a TOFR < 0.9 . The secondary outcomes were PACU stay length, ventilation time, chest radiography request, reintubation, and desaturation events.

Process measure: TOFR recorded (Fidelity 70%).

Balance measure: NMB and reversal agents dosing during anaesthesia and in PACU.

All demographic preoperative, intraoperative, and postoperative variables were defined a priori.

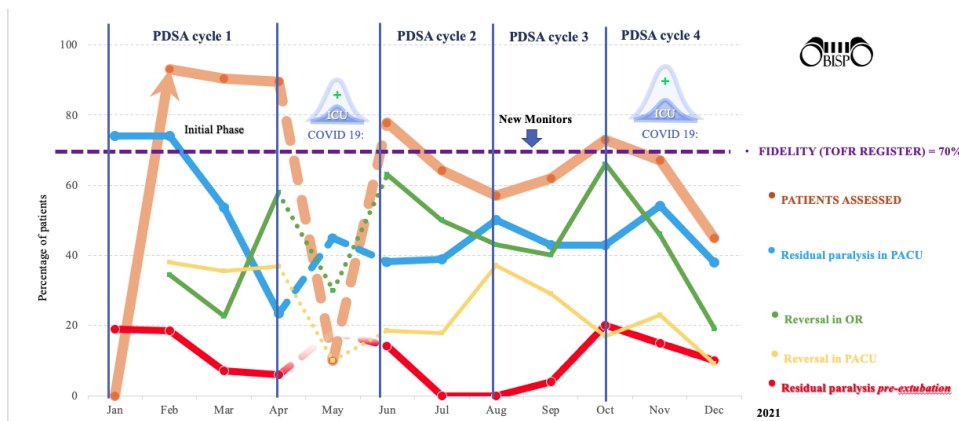
Preoperative data included American Society of Anesthesiologists (ASA) classification (1, 2, 3, 4 or 5), surgery type, and estimated glomerular filtration rate (eGFR) calculated using the CKD-EPI creatinine equation.

eGFR values were classified as normal or elevated (G1: > 90), mildly decreased (G2: 60-89), mildly to moderately decreased (G3a: 45-59), moderately to severely decreased (G3b: 30-44), severely decreased (G4: 15-29) and kidney failure (G5: < 15).

Datas were obtained from electronic records to build a single, de-identified database. TOFR was measured by either electromyography or acceleromyography using the following monitors: NMT Electron Sensor (GE HealthCare, Chicago, United States; Figure 1) and Philips Intellivue NMT monitor (Royal Philips Electronics, Amsterdam, The Netherlands; Figure 2).

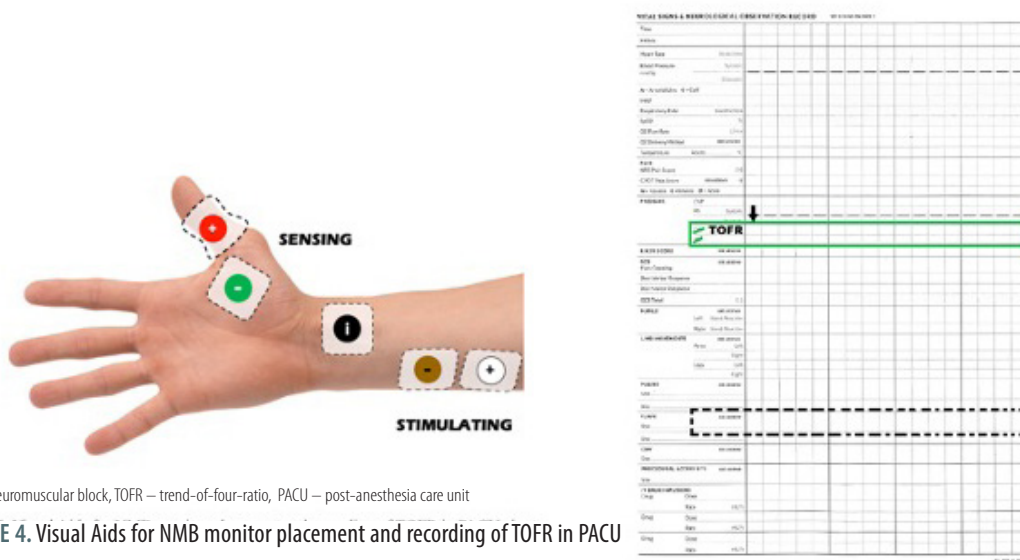


FIGURE 2. Philips Intellivue NMT monitor (Royal Philips Electronics, Amsterdam, The Netherlands)



OBISPO – Optimizing neuromuscular Blockade management for Improving patient Safety and Perioperative Outcomes, NMB – neuromuscular block, TOAR – trend-of ratio, PACU – post-anesthesia care unit, OR – operating room, COVID-19 – Coronavirus 19 pandemic wave, ICU – intensive care unit, PDSA cycle – plan-do-study-act

FIGURE 3. OBISPO quality improvement initiative – pilot phase (fast-track cardiac surgery) Monthly percentage of patients assessed by quantitative NMB monitor in PACU. Run Chart



NMB – neuromuscular block, TOFR – trend-of-four-ratio, PACU – post-anesthesia care unit

FIGURE 4. Visual Aids for NMB monitor placement and recording of TOFR in PACU chart

PDSA Cycle 1: Root cause analysis, process mapping, and evaluation of baseline data

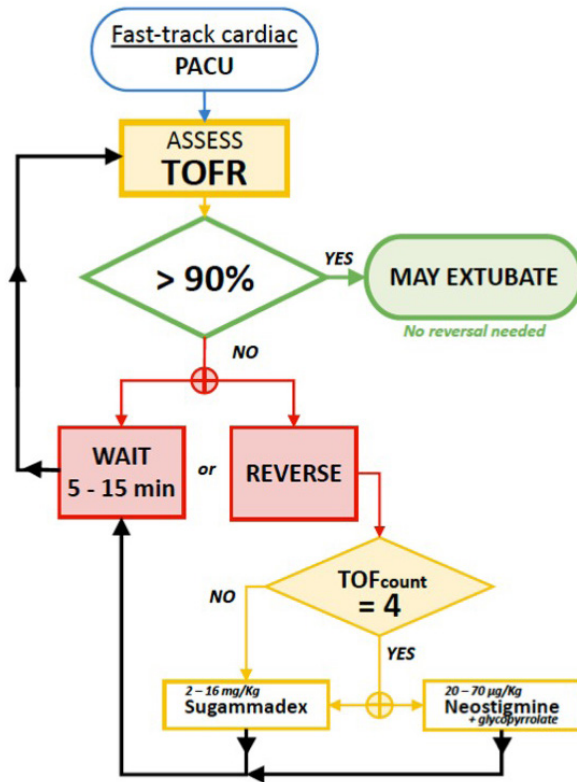
Initial meetings were held with the QI team to analyze the root cause using a fishbone diagram. The reasons for not monitoring NMB, such as (1) the absence of specific charts and alerts to monitor and document current practice, (2) practice traditions, (3) lack of awareness regarding current practice guidelines, (4) lack of reliable/sufficient monitors in the operating rooms and PACU areas, and (5) concerns about possible adverse events when using NMB monitors and pharmacological reversal agents, were discussed.

In addition to the absence of quantitative NMB recording, we observed a lack of protocol standardization for monitoring and administering pharmacological reversal agents resulting in variable and often unregistered clinical practices. When we per-

formed process mapping, most elective fast-track cardiac surgery patients were extubated without quantitative NMB monitoring assessment, whereas pharmacological reversal was often not recorded.

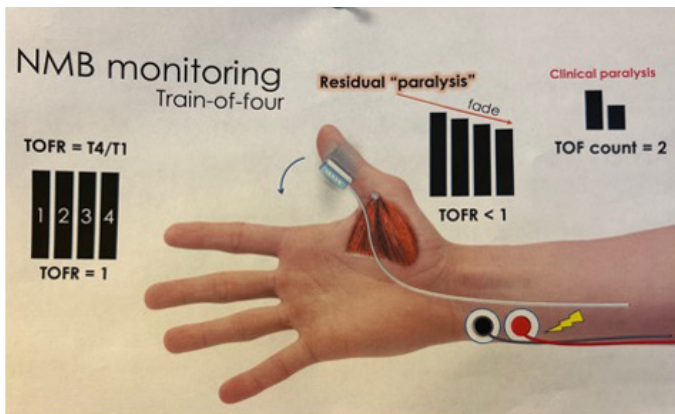
PDSA Cycle 2: Development of improvement strategies

The QI team designed educational group sessions for personnel (residents, fellows, anaesthesia staff, and nurses) within the circle of care for the baseline patient cohort. Education focused on evidence supporting the current guidelines regarding the use of NMB monitoring, reversal, and operation of quantitative NMB devices available at our institution. In addition, cognitive aids were displayed in the appropriate care spaces (cardiac operating rooms and fast-track PACU bays), including a figure demonstrating electromyogra-



PACU – post-anesthesia care unit, TOF – trend-of-four, TOFR – trend-of-four-ratio

FIGURE 5. Reversal strategy flowchart



TOF – trend-of-four, TOFR – trend-of-four-ratio, NMB – neuromuscular block

FIGURE 6. New NMT monitors placement and training visual aid for TOFR monitoring

phy electrode placement. A dedicated space for recording NMB assessments in PACU nursing charts, and electronic anaesthesia records were created (Figure 4) with an NMB management flowchart (Figure 5).

PDSA Cycle 3: Education and feedback

Educational refreshment training was held within the anaesthesia department by PACU nurses every two–three months, emphasizing the rationale

behind NMB monitoring and reversal practice standards. During this cycle, new NMT devices (Intellivue NMT monitor) were purchased and placed at each anaesthesia station as an improvement strategy. This change required trained personnel to operate the new accelerometers (Figure 6).

PDSA Cycle 4: Implementation assessment

After the results from the previous cycle, educational rounds were reinforced; we displayed the trends of ongoing outcomes. To understand the weaknesses and gaps in knowledge to be addressed at the end of the first year, all staff, residents, and fellows completed a survey (Table 4) regarding the use of NMB monitoring and the factors associated with the lack of use of quantitative NMB monitoring as the standard of care.

Statistical analysis

SPSS Statistics (IBM, USA, release 28.0) was used to analyze the data. The baseline characteristics of the patients, TOFR, residual paralysis, use of NMB reversal agents, complications, time of ventilation, and LOS in the PACU were calculated and presented as percentages (numbers), medians (percentiles), or means (standard deviations).

RESULTS

Of the 859 patients who underwent elective cardiac surgery at our institution between February and December 2021, 341 (40%) were transferred to the PACU for fast-track extubation. The population consisted of 238 (70%) male subjects with a median age of 62 years old (IQR [54–70]). Of the 341, 64 (19%) were classified as ASA 3 and 277 (81%) as ASA 4. Most of the patients had normal (152 [94%]) or mildly decreased (157 [46%]) eGFR.

Demographics, including the type of surgery, are presented in Table 1.

In the baseline cohort, on arrival at PACU, 236 (69%) TOFR were registered; 111 (47%) had TOFR < 0.9 before extubation, 24 (22%) had residual paralysis after extubation, 91 (27%) were extubated without TOFR monitoring, and 33 (10%) were transferred intubated to intensive care unit (ICU). All the patients received rocuronium as a paralyzing agent; the mean dose was 1.12 mg kg⁻¹ (0.23 mg kg⁻¹ h⁻¹). NMB reversal agents were used in 85 (25%) patients, and neostigmine in 61 (72%). During surgery, 146 (43%) patients received NMB reversal agents, 140 (96%) received neostigmine without quantitative NMB monitoring or confirmation of TOFR > 0.9 before arrival to PACU, 55 (39%) patients received < 0.04 mg/kg as a single dose (Table 2).

The overall results showed that patients had a mean ± standard deviation (SD) LOS in the PACU

TABLE 1. Overall results, patient's characteristics, and type of surgery

Patients	
Total elective cardiac	859 (100)
Fast-track	341(40)
Male sex	238 (70)
ASA 3	64 (19)
ASA 4	277 (81)
Median age (IQR)	62 (54–70)
Median weight (IQR)	88 (72–98)
CKD Classification (eGFR mL min ⁻¹ 1.73 m ⁻²)	
Normal or elevated: G1 (> 90)	152 (45)
Mild decreased: G2 (60–89)	157 (46)
Mildly to moderately decreased: G3a (45–59)	21 (6)
Moderately to severely decreased: G3b (30–44)	7 (2)
Severely decreased: G4 (15–29)	2 (0.5)
Kidney failure: G5 (< 15)	2 (0.5)
Type of surgery	
Coronary artery bypass (CAB)	128 (36)
Aorta surgery (ascending aorta or complex)	26 (8)
Valve surgery (repair or replacement)	36 (11)
Combined procedure (valve with CAB)	107 (31)
Others (congenital or myectomy)	44 (14)

Values are numbers (%) unless otherwise specified.

PACU – Post Anesthesia Care Unit, OR – Operating Room, CKD – chronic kidney disease, eGFR – estimated glomerular filtration rate [CKD-EPI – creatinine equation was used to estimate GFR], CAB – coronary artery bypass

TABLE 2. Register of neuromuscular blockade in PACU, doses of neuromuscular reversal agents and doses of rocuronium in OR

Patients	
TOF registered	236 (69)
TOFR < 0.9 on arrival to PACU	111 (47)
Extubated with TOFR < 0.9	24 (22)
Extubated with NO TOF monitored	91 (27)
No extubated in PACU	33 (10)
Patients re-intubated	0 (0)
Need of chest radiography	8 (2)
Need of increase of oxygen in PACU	13 (4)
Neuromuscular block reversal agents	
Use of Neostigmine in OR	140 (96)
Neostigmine dose in OR > 0.04 mg kg ⁻¹	85 (61)
Neostigmine dose in OR < 0.04 mg kg ⁻¹	55 (39)
Sugammadex use in OR	8 (5)
Use of Neostigmine in PACU	61 (72)
Sugammadex in PACU	26 (31)
Doses of Rocuronium in OR	
Total average dose (mg kg ⁻¹)	1.12
Average dose per hour (mg kg ⁻¹ h ⁻¹)	0.23

Values are numbers (%) unless otherwise specified.

TOF – train-of-four, TOFR – train-of-four ratio, PACU – post-anaesthesia care unit, OR – operating room

PDSA cycle*	Total of patients	Fast-track patients	TOFR register	Residual paralysis on PACU	Extubated in ICU	NMB reversal In OR	NMB reversal PACU	Increase in oxygen delivery	Re-intubation	Chest radiography	Time of ventilation in PACU (mean ± SD, min)	LOS in PACU (mean ± SD, min)
1	195	79 (40.5)	72 (91.0)	39 (54.0)	10 (12.6)	28 (35.4)	29 (36.7)	3 (3.79)	0	1 (1.2)	72±7	120±21
2	153	55 (35.9)	39 (70.9)	15 (27.2)	3 (5.4)	31 (56.3)	10 (18.1)	0	0	0	30±42	132±42
3	183	80 (43.7)	48 (60.0)	22 (27.5)	11 (13.7)	33 (41.2)	26 (32.5)	5 (6.2)	0	2 (2.5)	40±24	88±24
4	275	127 (46.1)	77 (60.6)	35 (43.7)	9 (11.2)	54 (67.5)	20 (25.0)	5 (6.2)	0	5 (6.2)	78±14	120±14

TABLE 3. Results of PDSA cycles

Values are numbers (%) unless otherwise specified.

*Cycle 1 included February, March, and April 2021. Cycle 2 included June and July 2021. Cycle 3 included August and September 2021. Cycle 4 included October, November, and December 2021.

TOFR – train-of-four ratio, NMB – neuromuscular block, PACU – post anesthesia care unit, OR – operating room, PDSA – plan-do-study-act, LOS – length of stay, SD – standard deviation, Min – minutes

TABLE 4. Survey: Use of NMB monitorization and factors associated with the lack of use of quantitative NMB monitoring as the standard of care

Answer choices	n (%)
Question 1: Before extubating patients who received muscle relaxants: How do you usually assess NMB recovery?¹	
Clinical (Spontaneous breathing, muscle strength, etc.)	29 (56.8)
Qualitative (visible response to peripheral nerve stimulation)	15 (29.4)
Quantitative (accelerometer or electromyography)	7 (13.7)
Question 2: What prevents you from adopting quantitative NMB monitoring into your routine practice?²	
Difficulties with NMT devices (not enough, difficult to be used, etc.)	57 (47.8)
A gap of knowledge (high prevalence in credibility on clinical and qualitative assessment)	51 (42.8)
Weakness in training	11 (9.2)
Question 3: What is your current position?³	
Staff < 5 years	8 (17.3)
Staff > 5 years	23 (50)
Fellow	11 (23.9)
Resident	4 (8.7)

¹Total of 51 answered. ²A total of 119 responses from 41 answered, 9 skipped. ³51 answered, 5 skipped.
NMB – neuromuscular block, NMT – neuromuscular transmission

of 87 ± 56 minutes (min) with a ventilation time of 55 ± 14 min. During their stay in PACU, eight (2%) patients underwent chest radiography, thirteen (4%) patients required increased oxygen delivery after extubation with no desaturation ($< \text{SpO}_2$ 90%) events observed, and no patients required reintubation (Table 2).

Over 46 weeks, and four PDSA cycles, the evolution of results included the percentage of patients eligible for fast-track extubation after elective cardiac surgery, TOFR register (fidelity) in the PACU, residual paralysis on arrival at the PACU, residual paralysis pre-extubation, and use of reversal in the OR and PACU (Figure 3). The effects of each PDSA cycle are presented in Table 3.

During PDSA cycle 1 (February to April 2021), 79 (40.5%) patients were eligible for fast-track. The mean TOFR registered was 91%, 39 (54%) patients had residual paralysis on arrival at PACU, 28 (35.4%) patients received NMB reversal in OR, and 29 (36.7%) of them in PACU. No reintubation was observed, ten (12.6%) patients were extubated in ICU, three (3.7%) patients required an increase in oxygen delivery, and one (1.2%) patient had chest radiography. The mean ventilation time was 72 ± 7 min, and the LOS in the PACU was 120 ± 21 min.

From May to June 2021, the COVID-19 pandemic's second wave interfered with the study because all elective cardiac procedures were cancelled. During this period, training was provided to PACU nurses, and evaluation of the study progress was conducted.

During PDSA cycle 2 (June to July 2021), 55 (35.9%) patients were eligible for fast-track extubation. The TOFR register decreased, but

the number of patients with residual paralysis also decreased. Fewer patients were extubated in ICU (12.6% vs. 5.4%) and no adverse events were observed. The use of NMB reversal in the OR increased, with a decrease in the use of reversal agents in the PACU. The duration of mechanical ventilation decreased but the LOS in the PACU increased.

New NMT devices were obtained between cycles 2 and 3. During the PDSA cycle 3 (August to September 2021), 80 (43.7%) patients were eligible for fast-track extubation, the TOFR register decreased by 10%, and residual paralysis persisted in 27% of the patients. A decrease in NMB reversal in the OR was observed (56.3% vs. 41.2%), with reversal agents use in PACU increasing from 18.1% to 32.5%. Regarding complications, five (6.2%) patients required an increase in oxygen delivery, two (2.5%) patients required chest radiography, and no reintubation episodes were observed. The ventilation time decreased by 40 ± 24 min, and the LOS in the PACU decreased to 88 ± 24 min compared to those in cycle 2.

The survey performed (Table 4) during PDSA cycle 4 (October to December 2021) consisted of three questions. Overall, we observed that 29 (56.8%) respondents used clinical assessment to assess NMB recovery and had difficulties using quantitative NMT monitors due to a lack of knowledge or bias, even though 23 (50%) of the responders were staff with more than five years of experience.

During the 4th PDSA cycle, the third wave of COVID-19 impacted clinical care. Of 275 patients, 127 (46%) were eligible for fast-track cardiac extubation. The TOFR register decreased (60.6%), with a further increase in residual paralysis to 43% and

an increase in the number of patients extubated in the ICU as well (11%). However, the use of NMB reversal agents in the OR increased to over two-thirds, with a commensurate decrease in the PACU. An increase in oxygen delivery was required in five (6.2%) patients and chest radiographs in five (6.2%) patients. An increase in ventilation time and LOS in the PACU was observed compared to that in cycle 3 (Table 3).

DISCUSSION

The main results of our study showed that a significant proportion (47%) of patients qualifying for fast-track extubation after elective cardiac surgery had residual paralysis upon arrival in PACU. Furthermore, 22% had residual paralysis after extubation, and 27% were not monitored using NMT. At the end of the initial phase, residual paralysis remained at 38%, but increased use of reversal agents was observed in the last PDSA cycle (67.5%).

These measurements improved over the study period, reaching a minimum fidelity of 70% for TOFR monitoring in the overall results. Historically, NMB assessment at our institution has been limited, primarily subjective, and poorly documented. Through our initiative, we addressed some of the root causes and changed the behaviour of the perioperative team responsible for monitoring and managing NMB.

Additionally, after the completion of the first part of this QI study, quantitative NMT monitoring became part of clinical practice in the PACU for fast-track cardiac surgical patients in our hospital. TOFR was routinely recorded in patients' electronic charts, and reversal agents were administered according to our protocol.

The results of our project complement the existing literature. Recently published guidelines by the American Society of Anesthesiologists (January 2023) recommend the routine use of quantitative TOFR monitoring [9], which corresponds to our project. All other major anaesthesia professional organizations, including the Canadian Anesthesiologists' Society [7], the European Society of Anaesthesia and Intensive Care [10], and the Association of Anaesthetists of Great Britain and Ireland [11], have strongly advised the use of quantitative NMT monitoring for many years. Moreover, evidence-based recommendations are based on multiple studies showing that residual muscular paralysis is a major contributor to postoperative respiratory complications [5].

Several initiatives addressed adherence to routine quantitative NMB monitoring in patients undergoing surgery with the use of NMB monitors. A recent publication by Díaz-Cambronero

et al. [12] described an effort to reduce residual paralysis in the postoperative period using an educational intervention across 34 centres in Spain. This study demonstrated that clinical practice behaviour changes were challenging; during their study, an educational aid regarding the use of quantitative NMT and reversal of NMB was used in multiple centres for six months. After this period, the investigators concluded that the educational intervention did not reduce the incidence of residual paralysis. However, they noticed an increase in the use of NMT and sugammadex as NMB reversal, with an associated decrease in postoperative pulmonary complications.

Weigel *et al.* [6] conducted a similar QI project in a single institution to monitor all patients in the OR to prevent residual NMB before tracheal extubation. They initially faced resistance from care providers regarding the adoption and use of quantitative NMB monitoring. After the full implementation of their QI initiative, TOFR > 0.9 improved from 1% to 92%. Attaining this endpoint required quantitative monitor placement in each anaesthetizing location and ongoing four-year educational efforts to elicit behaviour change. Both general and individual performance feedback systems were used. Additionally, real-time automated anaesthesia charting reminders and departmental leadership requesting TOFR documentation as an ongoing professional practice evaluation metric were fundamental to achieving success.

Rudolph *et al.* [13] evaluated the effects of a QI initiative optimizing neostigmine use to antagonize NMB and its effect on postoperative pulmonary complications, costs, and duration of hospital stay. The authors demonstrated that altered practice behaviours included neostigmine dose reductions, decreased excessive neostigmine doses, and improved intraoperative TOFR documentation. Furthermore, the QI initiative was associated with reduced hospital stay and costs.

Bedsworth *et al.* [14] developed an initiative to improve anaesthesia providers' knowledge of NMB pharmacology, physiology, and monitoring. After completing their project, an analysis was conducted to assess changes in practice regarding the use of quantitative monitoring and dosing of NMB agents and neostigmine. Quantitative monitoring increased significantly from 14.0% in the pre-initiative group to 48.0% after the completion of the QI project. This quantitative monitoring initiative successfully increased the use of quantitative NMB monitors; however, it did not affect providers' overall dosing practices for NMB agents or neostigmine. This study stated that adopting research findings into routine clinical practice is a slow process

that sometimes fails to sustain long-term practice changes, as evidenced by a decrease in NMT monitoring over time.

Drzymalski *et al.* [15] conducted a single-center study that included cognitive aid to help clinicians to choose between NMB reversal agents. This project was developed due to an increased cost after the introduction of sugammadex in their institution. The authors hypothesized that sugammadex use and the associated costs would decrease after the introduction of educational aids. This initiative compared sugammadex administrations and costs before and after aid application. To perform an interrupted time-series analysis, an investigation of the baseline situation regarding the number of sugammadex vials was used. The associated cost was analyzed before initiative initiation, and monthly progress evaluation was conducted. After 21 months, there were 509 fewer sugammadex administrations than predicted per 1,000 general anaesthetics. This study facilitated significant change in clinical practice but took two years of education to change clinical behaviour. In the discussion, the authors acknowledge that the outcome was not only related to the aid itself but multiple factors, especially collaboration from multiple departmental leaders and continuous reinforcement of its importance were involved.

In summary, all the aforementioned studies showed that QI projects aimed at improving quantitative NMB monitoring and safe extubation (TOFR > 0.9) required multiple interventions and required several years to achieve their goals.

Our study had several limitations. The COVID-19 outbreaks affected our study, with cancellation or postponement of elective surgeries. Consequently, the training and knowledge were outside of routine practice once the PACU was transformed into a regular ICU. Later, during the study, a different brand of quantitative NMB monitor replaced those used at the beginning of the study (both accelerometers, but with different limitations). This change affected the results of the next evaluation cycle, and new training and adherence to the changes in devices were required. We observed that, regardless of persistent training and education, a high incidence of residual paralysis (27.5%) was observed at the end of the study. This result is potentially related to multiple changes in NMT monitors and the short study time, implying that more time is required to change clinicians' behaviour.

Finally, changes in clinical practice are challenging, and continuing education with process evaluation is mandatory. The time required to observe a significant difference in behaviour represents the prolonged period required for educational interventions to merge with physicians' practice. In

this context, our observation period was relatively short; however, we focused only on the first part of the OBISPO initiative.

CONCLUSIONS

Our study showed that clinician behaviour change is one of the most challenging issues in the perioperative care of patients requiring NMB. Despite these challenges, we were able to achieve several goals, and TOFR is now routinely monitored before extubation following cardiac surgical procedures. Continuous teaching and QI initiatives that focus on the use of quantitative NMB monitors and adequate administration of reversal agents are mandatory to progress and ultimately improve perioperative outcomes, including the reduction of postoperative pulmonary complications. Changing current practices regarding the safe use of NMB agents remains difficult. Therefore, new proposals and studies are required to promote changes in current practice and clinicians' behaviour.

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REFERENCES

1. Butterly A, Bittner EA, George E, Sandberg WS, Eikermann M, Schmidt U. Postoperative residual curarization from intermediate-acting neuromuscular blocking agents delays recovery room discharge. *Br J Anaesth* 2010; 105: 304-309. doi: 10.1093/bja/aeq157.
2. Grabitz SD, Rajaratnam N, Chhagani K, et al. The effects of postoperative residual neuromuscular blockade on hospital costs and intensive care unit admission. *Anesth Analg* 2019; 128: 1129-1136. doi: 10.1213/ANE.0000000000004028.
3. Thevathasan T, Shih SL, Safavi KC, et al. Association between intraoperative non-depolarising neuromuscular blocking agent dose and 30-day readmission after abdominal surgery. *Br J Anaesth* 2017; 119: 595-605. doi: 10.1093/bja/aex240.
4. McLean DJ, Diaz-Gil D, Farhan HN, Ladha KS, Kurth T, Eikermann M. Dose-dependent association between intermediate-acting neuromuscular-blocking agents and postoperative respiratory complications. *Anesthesiology* 2015; 122: 1201-1213. doi: 10.1097/ALN.0000000000000674.
5. Kirmeier E, Eriksson LI, Lewald H, et al. Post-anaesthesia pulmonary complications after use of muscle relaxants (POPULAR): a multicentre, prospective observational study. *Lancet Respir Med* 2019; 7: 129-140. doi: 10.1016/S2213-2600(18)30294-7.
6. Weigel WA, Williams BL, Hanson NA, et al. Quantitative neuromuscular monitoring in clinical practice: A professional practice change initiative. *Anesthesiology* 2022; 136: 901-915. doi: 10.1097/ALN.0000000000004174.
7. Dobson G, Chow L, Filteau L, et al. Guidelines to the practice of anesthesia – revised edition 2020. *Can J Anesth* 2020; 67: 64-99. doi: 10.1007/s12630-019-01507-4.
8. Fortier L-P, McKeen D, Turner K, et al. The RECITE Study: a Canadian prospective, multicenter study of the incidence and severity of residual neuromuscular blockade. *Anesth Analg* 2015; 121: 366-372. doi: 10.1213/ANE.0000000000000757.
9. Thilen SR, Weigel WA, Todd MM, et al. 2023 American Society of Anesthesiologists practice guidelines for monitoring and antagonism of neuromuscular blockade: A report by the American Society of Anesthesiologists task force on neuromuscular blockade.

- Anesthesiology 2023; 138: 13-41. doi: 10.1097/ALN.0000000000004379.
10. Fuchs-Buder T, Romero CS, Lewald H, et al. Peri-operative management of neuromuscular blockade: A guideline from the European Society of Anaesthesiology and Intensive Care. *Eur J Anaesthesiol* 2023; 40: 82-94. doi: 10.1097/EJA.0000000000001769.
 11. Checketts MR, Alladi R, Ferguson K, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015: association of Anaesthetists of Great Britain and Ireland. *Anaesthesia* 2016; 71: 85-93. doi: 10.1111/anae.13316.
 12. Díaz-Cambrero Ó, Mazzinari G, Errando CL, et al. An educational intervention to reduce the incidence of postoperative residual curarisation: A cluster randomised crossover trial in patients undergoing general anaesthesia. *Br J Anaesth* 2023; S0007-0912: 00113-7. doi: 10.1016/j.bja.2023.02.031.
 13. Rudolph MI, Chitilian HV, Ng PY, et al. Implementation of a new strategy to improve the peri-operative management of neuromuscular blockade and its effects on postoperative pulmonary complications. *Anaesthesia* 2018; 73: 1067-1078. doi: 10.1111/anae.14326.
 14. Bedsworth MB, Harris EM, Vacchiano CA, Thompson JA, Grant SA, Goode VM. Evaluating a quality improvement initiative to increase anesthesia providers' use of and understanding of quantitative neuromuscular monitors. *AANA J* 2019; 87: 357-363.
 15. Drzymalski DM, Schumann R, Massaro FJ, Trzcinka A, Azocar RJ. Effect of a cognitive aid on reducing sugammadex use and associated costs. *Anesthesiology* 2019; 131: 1036-1045. doi: 10.1097/ALN.0000000000002946.