# Does an educational intervention on quantitative neuromuscular monitoring increase CRNA utilization of quantitative neuromuscular monitoring and improve patient outcomes?

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## Abstract

**Background**: The administration of neuromuscular blocking drugs often accompanies general anesthesia. Subjective neuromuscular monitoring techniques do not consistently detect residual neuromuscular blockade before tracheal extubation. The current recommendation is to achieve a train-of-four ratio (TOFr) of at least 0.9 before tracheal extubation. This can only be accomplished by using quantitative neuromuscular monitoring (QNM). Patients are at an increased risk of respiratory complications and increased length of stay in the PACU when QNM is not used. **Methods**: This DNP project was a quality improvement (QI) initiative to increase the usage of QNM and improve patient outcomes. A pre-intervention survey was administered to the staff before an educational intervention on the usage of QNM. One month later, a post-intervention survey was given to the staff. Knowledge, comfort level, perceptions, and barriers were measured with the surveys. De-identified patient chart reviews were also analyzed to evaluate patient outcomes. **Results**: A two-sample t-test compared pre-intervention PACU times to the post-intervention PACU times. There was no significant difference in PACU times between the two groups (p=0.81). Survey results did not reveal significant changes in knowledge, comfort level, or perceptions of QNM when comparing pre/post-survey responses. However, there was a significant increase in CRNAs who acknowledged existing barriers to using QNM after the intervention (pre-intervention - 46%; post-intervention - 69%). **Conclusion**: QNM is effective in preventing the incidence of residual neuromuscular blockade which decreases the risk of respiratory complications postoperatively. However, barriers such as time constraints and surgical positioning prevent CRNAs at the site from routinely using QNM to monitor neuromuscular blockade.

## Background and Significance

Administering non-depolarizing neuromuscular blocking drugs is common during the administration of general anesthesia. This temporarily immobilizes the patient, creating optimal surgical and intubating conditions. Historically, anesthesia providers monitor a train of four count (TOFc) using a peripheral nerve stimulator (PNS) to assess the depth of neuromuscular blockade (NMB) intraoperatively. The use of a peripheral nerve stimulator is a subjective measure requiring tactile and visual senses to estimate the depth of NMB. Consequently, using a PNS will not ensure the patient fully recovers from NMB before tracheal extubation. The current recommendation for ensuring recovery from neuromuscular blockade is to achieve a train of four ratio (TOFr) greater than 0.9 (Blobner et al., 2022). TOFr reliably quantifies the fade in twitch amplitude when evaluating a sequence of four twitches. TOFr measures and compares the strength of the fourth twitch to the first. Therefore, a TOFr of 0.9 or greater signifies minimal fade. In other words, the fourth twitch in the sequence is at least 90% as strong as the first. A quantitative neuromuscular monitor (QNM) is the only tool that accurately measures this data.

Visually, humans cannot detect residual neuromuscular blockade using a PNS after administering reversal agents. This remains true when clinical signs, such as sustained head lift, adequate tidal volumes, and maximum vital capacity, are combined with using a PNS. A recent narrative review by Murphy and Brull stated that 32% of patients monitored intraoperatively with a PNS exhibited a TOFr less than 0.9 upon entry to the PACU. In contrast, only 1.6% of patients had a TOFr less than 0.9 when QNM was utilized (2022). Furthermore, postoperative residual neuromuscular blockade is not a benign condition. A TOFr $< 0.9$ upon arrival in the PACU makes patients 3-3.5 times more likely to have respiratory complications (Murphy & Brull, 2022). In a study by Saager and colleagues, patients with TOFr $< 0.9$ required more antibiotics and supplemental oxygen following discharge from the PACU; also, the length of stay in the PACU was increased on average from 243 minutes to 323 minutes when patients had residual blockade as evidenced by a TOFr < 0.9 (2019).

Hospital policies vary regarding the use of neuromuscular reversal agents. Until recently, neostigmine, an anticholinesterase agent, was the primary medication used to antagonize neuromuscular blockade. This drug's ability to completely reverse neuromuscular blockade is limited, and neostigmine cannot reverse profound NMB. A systematic review by Raval et al. revealed that residual blockade was evident in 100% of patients 2 minutes after receiving the recommended dose of neostigmine for reversal. Further, 95% of patients given neostigmine to antagonize profound neuromuscular blockade exhibited residual blockade 60 minutes after administration (2020).

Despite the existing evidence, most hospitals in the US do not use quantitative neuromuscular monitoring, and some facilities solely use neostigmine to reverse neuromuscular blockade. Certified Registered Nurse Anesthetists (CRNAs) at the project site have access to quantitative neuromuscular monitors, but few CRNAs utilize this tool intraoperatively. In addition, neostigmine is the first-line agent currently used to reverse neuromuscular blockade at this facility. Based on current evidence, a significant percentage of patients presenting to the PACU at this facility are likely experiencing residual NMB. An educational intervention to teach CRNAs about the benefits of using quantitative neuromuscular monitoring intends to increase the usage of QNM and directly improve patient outcomes.

## Purpose Statement

This Doctor of Nursing Practice (DNP) project aims to increase the usage of quantitative neuromuscular monitoring (QNM) among CRNAs, thus improving patient outcomes perioperatively. The objective will be addressed by providing an educational intervention summarizing the current evidence supporting the use of QNM. The goal is to answer the following question: Will CRNAs at a large urban hospital increase their usage of QNM following an educational intervention and will this directly improve patient outcomes?

## Review of the Current Literature

A literature search was conducted to identify articles articulating the relative benefits of using quantitative neuromuscular monitoring to ensure full recovery from neuromuscular blockade. The databases searched were PubMed and the Cumulative Index to Nursing and Allied Health Lite (CINAHL). The search used the following keywords: *quantitative neuromuscular monitoring, neostigmine, residual weakness, residual neuromuscular blockade, postoperative complications/outcomes, anesthesia, post-anesthesia care unit (PACU), obesity, and elderly.*

An initial, general search of *quantitative neuromuscular monitoring* and *anesthesia* yielded 23 articles from 2002-2022. Using other keywords listed above, more specific searches were then made to explore other key points surrounding the topic. The search results included systematic reviews, randomized control trials, meta-analyses, quality improvement initiatives, prospective observational studies, and literature reviews. Twenty-four articles were selected after examining the reports for quality and applicability to this project. Quality was determined by ensuring the study was peer-reviewed and had a large sample size. Most chosen articles were published between 2017 and 2022 to strengthen relevance. Sources referencing pediatrics were excluded because this project focuses on adult patients. Only articles that evaluated patients receiving non-depolarizing neuromuscular blocking drugs such as rocuronium and vecuronium were included because these are the only two drugs routinely given at the project site during general anesthesia. Articles without full-text access were also excluded.

**Neuromuscular Monitoring**

In a sample of 3,000 anesthesia providers, 90% agreed that quantitative neuromuscular monitoring (QNM) should be used when patients receive general anesthesia (Bedsworth, 2019). However, anesthesia providers have historically used a peripheral nerve stimulator to monitor the depth of neuromuscular blockade intraoperatively. Fülesdi and Brull suggest that anesthesia providers can become resistant to "unlearn" their current practices despite evidence suggesting QNM is a more precise tool (2022).

***Subjective Neuromuscular Monitoring***

A peripheral nerve stimulator (PNS) is an instrument that delivers an electrical impulse to a nerve which results in a muscle contraction. A train of four (TOF) is a sequence of four electrical impulses delivered to a peripheral nerve at 2 Hz and is commonly used to estimate the degree of neuromuscular blockade. With subjective monitors, the anesthesia provider must visually or tactilely compare the strength of the first and fourth twitches to estimate the depth of neuromuscular blockade (Blobner et al., 2022). The inability to quantify the train of four ratio is the primary shortcoming of the PNS. When four twitches are present in the TOF, quantitative monitors reliably detect fade in twitch amplitude by displaying a TOFr. The TOFr compares the strength of the fourth twitch to the first. Therefore, a TOFr of 0.9 indicates that the fourth twitch in the sequence is 90% as strong as the first. A TOFr $\geq 0.9$ indicates to the provider there is minimal fade, and neuromuscular function has either spontaneously recovered or neuromuscular blockade has been adequately antagonized (Blobner et al., 2022). The current recommendation for safe tracheal extubation following surgery is a TOFr ≥ 0.9, and this can only be accurately determined using QNM (Azizoğlu & Özdemir, 2021; Carvalho et al., 2020).

Many anesthesia providers rely on a PNS and clinical signs to decide when a patient can safely be extubated. Notably, a non-depolarizing neuromuscular blocking drug can occupy 70% of a patient's nicotinic receptors with a TOFr of 0.9. Regardless of experience, a clinician can only detect fade with a TOFr of 0.4 or less (Fülesdi & Brull, 2022). This suggests clinicians using a PNS could assume that a patient has fully recovered from NMB when the TOFr is still less than 0.9. Clinical signs such as tidal volume, vital capacity, head lift, and grip strength have traditionally been assessed to verify recovery from NMB. However, as described by Blobner et al., normal tidal volumes can be achieved with a TOFr of 0.1, and normal vital capacity was observed in patients with a TOFr of 0.6. Furthermore, a sustained five-second head lift was achieved by some patients with a TOFr of 0.3 (2022). Their report concludes anesthesia providers must gauge neuromuscular blockade with QNM to achieve the highest degree of patient safety while avoiding being misled by subjective data and clinical indicators of recovery.

***Quantitative Neuromuscular Monitoring***

This project will be conducted at a large urban hospital where each operating room is equipped with an acceleromyograph QNM. These monitors have been shown to reduce the frequency of residual post-operative neuromuscular blockade (rNMB).

The transducer of the acceleromyography QNM device is placed on the thumb with electrodes applied along the course of the ulnar nerve. When an electrical impulse is delivered to the ulnar nerve, the adductor pollicis muscle contracts causing thumb movement. The resulting movement is measured and quantified, producing an accurate TOFr (Dunworth, 2018). Using

QNM eliminates dependence on subjective assessment, and the presence of rNMB may be excluded before tracheal extubation.

***Adductor Pollicis vs. Orbicularis Oculi***

Twenty years ago, the recommended TOFr for safe tracheal extubation was believed to be 0.7. However, numerous cases of increased upper airway obstruction and compromised protective airway reflexes at a TOFr from 0.7 to 0.9 were reported. This led to the updated recommendation for safe tracheal extubation with a TOFr ≥ 0.9 (Blobner et al., 2022).

According to Miller's Anesthesia *7th Edition,* the recovery profile of the adductor pollicis muscle parallels the upper airway muscles. Alternatively, the orbicularis oculi muscle parallels the recovery profile of the diaphragm and larynx. The onset and recovery from NMBDs are much faster for the diaphragm than for the upper airway muscles (Miller, 2015). Clinicians may overestimate the patient's ability to protect their upper airway when there is no perceivable fade in the TOFc of the orbicularis oculi muscle. In practical terms, this suggests patients are at increased risk for upper airway obstruction after tracheal extubation if subjective monitoring is used at the orbicularis oculi muscle. The provider should measure a TOFr ≥ 0.9 at the adductor pollicis to confidently rule out rNMB of the upper airway muscles which decreases the risk of upper airway obstruction following tracheal extubation (Blobner et al., 2022; Fülesdi & Brull, 2022).

**Residual Neuromuscular Blockade**

The most significant independent factor for increased postoperative pulmonary complications is residual neuromuscular blockade (Murphy & Brull, 2022).

***Incidence of Residual Neuromuscular Blockade after Extubation***

Considering the following studies, neostigmine was used to reverse NMB unless otherwise reported. A meta-analysis by Carvalho et al. focused on the frequency of rNMB postoperatively. The researchers determined quantitative neuromuscular monitoring was superior to other qualitative methods (2020). When neuromuscular blockade is monitored with a PNS, 32%-64.7% of patients exhibited a TOFr < 0.9 after extubation in the operating room, and 11.7-42% of patients arrived to the PACU with a TOFr < 0.9. However, when QNM was used, only 1.6% - 14.5% had TOFr < 0.9 after extubation in the operating room, and only 4.5% of patients had TOFr < 0.9 upon arrival to the PACU (Azizoğlu & Özdemir, 2021; Murphy & Brull, 2022; Raval et al., 2020; Saager et al., 2019). When Murphy et al. compared using acceleromyography QNM with the conventional PNS monitoring, they found 13.3% of patients arrived to the PACU with a TOFr < 0.7 when monitored with PNS and 0% had TOFr < 0.7 when acceleromyograph QNM was used (2008). Azizoğlu and Özdemir evaluated the clinical effect of re-administering NMB drugs after induction. They noted 42.8% of the patients who received a second dose of NMBD had TOFr < 0.9 upon entry to the PACU (2021).

***Post-operative Pulmonary Complication***

Administering any nondepolarizing neuromuscular blocking drug during surgery increases the risk of postoperative pulmonary complications by 4.4% (Blobner et al., 2020). Murphy and Brull suggest patients are 3 to 3.5 times more likely to have a respiratory event following surgery when the TOFr < 0.9 before extubation (2022). Blobner et al. further suggest if patients reach a TOFr > 0.95 before extubation, their risk for pulmonary complications is reduced by 3.5% (2020). Further, patients with rNMB require more supplemental oxygen, antibiotics, and respiratory therapy care following discharge from the PACU than patients without rNMB (Saager et al., 2019). Murphy and colleagues reported that patients monitored with acceleromyography experienced no SpO2 desaturations below 90% and did not require airway support from the time of extubation to admission to the PACU. Among patients monitored with a PNS, 21.1% had SpO2 desaturations below 90%, and 11.1% required an airway intervention to maintain airway patency (2008). Twenty-one studies measuring postoperative outcomes showed significantly higher rates of acute respiratory events in patients with TOFr < 0.9 (Raval et al., 2020).

### *Length of Stay in PACU*

Patients with rNMB experience more acute respiratory complications, leading to more time in the recovery room. Butterly et al. found patients with rNMB took an average of 75 minutes longer to reach “PACU discharge readiness” (2010). Other sources from a systematic review report that PACU length of stay increases from 6 to 100 minutes when patients’ NMB is not adequately reversed (Raval et al., 2020).

### *Overall Cost*

The longer patients stay in the PACU, the more resources are utilized, leading to higher costs. Edwards and colleagues conducted an observational study at Temple University Hospital comparing costs between patients with and without postoperative respiratory complications related to rNMB. They estimated the average cost of patients without rNMB to be $14,522, whereas patients diagnosed with pneumonia or needing reintubation after surgery averaged $50,895. The total additional cost to the hospital per year for patients having postoperative pulmonary complications was estimated to be 6.9 million dollars. The researchers suggested that using QNM and eliminating rNMB would lead to an annual 60% expense reduction (Edwards et al., 2021).

## Reversal Agents

***Neostigmine***

Historically, neostigmine has been the most frequently administered NMB reversal drug. Some facilities use this drug exclusively to reverse NMB. Neostigmine is an anticholinesterase drug that prevents acetylcholine metabolism. Consequently, more acetylcholine is available at the neuromuscular junction to bind with the nicotinic cholinergic receptors as the non-depolarizing neuromuscular blocking drug disengages from the receptor. The recommended dose of neostigmine is 40-70 mcg/kg, and it must be given with an antimuscarinic drug to prevent bradycardia, bronchospasm, excessive salivation, and other muscarinic effects. The most significant shortcoming of neostigmine is its ceiling effect. Once all acetylcholinesterase is inhibited, giving more medication does not increase the antagonism of NMB (Swerdlow & Osborne-Smith, 2022).

The drug's ability to reverse different levels of NMB was examined in a systematic review by Raval and colleagues (2020). Among patients with moderate NMB (TOFc 1-3), rNMB was noted in 100% of patients 2 minutes after an appropriate dose of neostigmine, 82% after 6 minutes, 39% after 15 minutes, and 14% after 60 minutes. The researchers also examined the ability of neostigmine to reverse deep NMB (post-tetanic count >/= 1). The results showed 100% of patients had rNMB at 2-10 minutes after an appropriate dose, 99% at 15 minutes, 95% at 30 minutes, and 39% at 60 minutes (Raval et al., 2020).

In another sample of 995 patients, Tajaate and colleagues reached slightly different conclusions. Their analysis showed an average of 17.1 minutes to achieve adequate recovery from deep NMB following a full dose of neostigmine (70 mcg/kg). It took an average of 11.3 minutes to reverse moderate blockade after receiving 56 mcg/kg of neostigmine and 8 minutes to reverse shallow block with 40 mcg/kg of neostigmine. Tajaate et al. also measured a statistically significant difference in reversal time based on the type of general anesthetic. When TIVA was administered, neostigmine reversed moderate blockade in 8.2 minutes versus 21.1 minutes when volatile agents were used (2018). Their recommendation is to withhold administration of neostigmine until NMB spontaneously recovers to a shallow blockade or allow at least 15 minutes after an appropriate dose of neostigmine is administered. This time interval would allow neostigmine to reach its peak effect before tracheal extubation (Raval et al., 2020; Tajaate et al., 2018).

### *Sugammadex*

Sugammadex is more effective than neostigmine for the antagonism of NMB. Although more effective, it is more expensive than neostigmine, and some facilities only permit its use in the case of an emergency. Sugammadex irreversibly binds with steroid-based NMB drugs and reverses the concentration gradient away from the neuromuscular junction. The kidneys excrete the newly formed drug complex. Sugammadex can reverse moderate NMB with a 2 mg/kg dose and deep NMB with 4 mg/kg. It is 3-8 times faster and more predictable at antagonizing NMB than neostigmine and does not have a ceiling effect (Swerdlow & Osborne-Smith, 2022). Sugammadex has three times more affinity for rocuronium than vecuronium (Fülesdi & Brull, 2022). Raval et al. reported that 42% of patients had TOFr < 0.9 upon admission to the PACU when patients were reversed with neostigmine, but only 0.3% had a TOFr < 0.9 when reversed with sugammadex (2020). Sugammadex is more predictable and efficient at reversing NMB than neostigmine.

## High-Risk Populations

### *Obesity and Postoperative Complications*

Among 255 patients studied at a community hospital, the incidence of rNMB was more prevalent in patients with a higher BMI (Saager et al., 2019). Obese patients are more likely to have obstructive sleep apnea and are more prone to airway closure during normal sleep. Obese patients have an increased risk of postoperative respiratory complications when rNMB is combined with the residual sedative effects following general anesthesia (Fülesdi & Brull, 2022).

***Elderly and Postoperative Complications***

Elderly patients also have an increased risk for postoperative pulmonary complications due to physiologic changes, comorbidities, decreased muscle mass, and reduced ability to regulate body temperature. With reduced organ function, it takes longer for elderly patients to metabolize medications, effectively increasing the duration of action of NMBDs (Fülesdi & Brull, 2022; Murphy et al., 2015).

Pharyngeal dysfunction was detected in 37% of awake volunteers over 65. Pharyngeal dysfunction can lead to airway obstruction and silent aspiration. Residual NMB increases pharyngeal dysfunction in the elderly by 71% (Cedborg et al., 2014; Murphy et al., 2015). Compared to younger patients receiving similar anesthetic management, elderly patients were almost twice as likely to experience rNMB in the PACU than younger patients (58% vs. 30%). They experienced more episodes of hypoxemia, airway obstruction, noticeable muscle weakness, and spent more time in the PACU (Murphy et al., 2015).

**Barriers**

The most significant barrier to change is for anesthesia providers to unlearn their old subjective neuromuscular monitoring habits. They tend to have disproportionate confidence in their clinical judgments and qualitative monitors (Fülesdi & Brull, 2022). Furthermore, in a fast-paced operating room, anesthesia providers want to be efficient and avoid delays for the surgical team. Another significant barrier is the time required to place the QNM and obtain a baseline TOFr during induction before administering neuromuscular blocking drugs. The last barrier identified is surgical positioning. This will only be a potential barrier with the acceleromyography QNM when the surgeon requires the arms to be tucked for the procedure. These barriers can be addressed by introducing electromyography QNM to the CRNAs as this type of monitor does not require the full range of motion of the patient's thumb. Fülesdi and Brull (2022) reveal that utilizing QNM should only add 30 seconds to starting a case for anesthesia providers trained with the devices. By giving a thorough demonstration of how to apply and use the monitors properly, the time necessary to apply the monitor should be reduced.

## Conceptual Framework/Theoretical Model

Lewin's Theory of Change suggests behavior is a product of a group's environment. As discussed previously, anesthesia providers are creatures of habit, and it can be challenging to change established behaviors. According to Lewin, for a QI initiative to be effective, the PI must strengthen the motivating factors for a specific behavioral change while weakening any barriers hindering the change. Three stages constitute Lewin's Theory of Change (Shirey, 2013).

1. The first stage is "unfreezing." During this initial stage, the PI must learn the environment before attempting to change behaviors. A thorough assessment of the environment allows the researcher to identify a problem, motivate others to see a need for change, and formulate a solution to the problem (Shirey, 2013). Current literature reveals strong evidence for the use of QNM. Despite having the resources to use QNM intraoperatively, anesthesia providers at this clinical facility collectively neglect to do so. This will be the behavior that is targeted for change. The unfreezing stage also includes the identification of barriers to change.

2. The second stage of Lewin's theory is moving or transitioning (Shirey, 2013). For change to occur, the CRNAs must be taught how to apply and use QNM properly. Ideally, this will promote optimistic feelings among the staff related to QNM. The goal is for the CRNAs to become comfortable with the monitors and, therefore, be more willing to use them intraoperatively.
3. "Refreezing" is the third stage of this theory. It involves engraining the new behavior into the culture and practice of the facility (Shirey, 2013). Making QNM the new standard will be a challenge, but the change can be sustained over time if CRNAs trust the credibility of QNM. If the change is not sustained over time, conducting another quality improvement initiative will be crucial to address the identified barriers.

## Methods

Current evidence demonstrates that QNM reduces the incidence of rNMB when administering nondepolarizing neuromuscular blocking drugs. Studies have shown that 40-65% of patients in the postoperative anesthesia care unit experience residual neuromuscular blockade (rNMB) when anesthesia providers use subjective neuromuscular monitoring to guide the administration of anticholinesterase-based reversal agents (Bedsworth, 2019; Saager et al., 2019). The Certified Registered Nurse Anesthetists (CRNAs) at one large urban hospital have access to quantitative neuromuscular monitoring intraoperatively. Still, nearly all the CRNAs use subjective monitoring techniques.

Before any implementation, a pre-education survey was given to the CRNA staff. Next, the staff was given an educational presentation on the benefits of using QNM (Appendix D). A follow-up survey was distributed to the CRNAs a few weeks after the education. An equally important objective of this practice improvement project is to identify the barriers preventing

CRNAs from adopting QNM. Identifying barriers can help the PI understand why CRNAs resist change and lay the foundation for a future research project to eliminate the identified barriers.

### *Design*

This DNP project was a quality improvement initiative to increase QNM use. Knowledge, perceptions, and utilization of QNM were quantitatively measured using a pre-post survey design. Following the administration of the pre-survey, an educational intervention was given to all the CRNA staff. Deidentified patient information was also reviewed to obtain a more precise measurement of increased QNM usage and patient outcomes. Convenience sampling was used by surveying all the available CRNA staff and by reviewing all the patient records that met the inclusion criteria. An email containing the educational information and survey was sent to all CRNA staff to ensure everyone had been exposed to the intervention. Convenience sampling will allow for the largest sample size and provide the most measurable data.

The educational presentation was advertised using email reminders. This meeting replaced a staff meeting on a late start day. Each CRNA staff member who completed the pre- and post-surveys was entered to win a drawing for a $30 Amazon gift card. The drawing rewarded one CRNA who participated in the study. This information was used during the advertising phase to incentivize participation in the study.

### *Translational Framework*

An evidence-based framework provides a structured pathway throughout the practice improvement process. The IOWA Model was most appropriate for this DNP project because it aims to improve patient outcomes using current best practices. The IOWA Mode can be characterized by a series of eight steps: (1) identify a "trigger" or clinical problem at an organization, (2) assess the significance of the problem to the organization, (3) develop a research team that will implement an organizational change, (4) evaluate what the current literature says about the problem being investigated, (5) synthesize the sources being reviewed in the previous step, (6) determine if the evidence is significant to implement a practice change, (7) carry out the practice change, (8) examine the results following the change in practice (Brown, 2014).

***Population***

The inclusion criteria for the patient chart reviews were as follows: eighteen years or older, general anesthesia with an endotracheal tube, a laparoscopic case requiring the administration of nondepolarizing neuromuscular blocking drugs (rocuronium or vecuronium), extubation is planned at the end of the case in the operating room. To participate in the surveys for this project, one was required to be a CRNA employed by the project site.

***Setting***

A signed letter of support was obtained from the facility to be submitted to the University of North Carolina at Greensboro (UNCG) IRB. The letter permitted the PI to give an educational intervention on quantitative neuromuscular monitoring at the facility. UNCG granted the PI IRB approval on June 5, 2023. IRB approval was later obtained from the project site on August 18, 2023. The project site is a large, urban medical center. This site was chosen because recently, the American Society of Anesthesiologists (ASA) recommended QNM be used to monitor neuromuscular blockade, and that sugammadex should be administered to reverse steroid-based neuromuscular blockade before tracheal extubation (Thilen et al., 2023). At this facility, there is a diversity of adult surgical cases requiring general anesthesia, each operating room is equipped with an acceleromyography quantitative neuromuscular monitor, and the anesthesia staff still use neostigmine as the first-line drug to reverse neuromuscular blockade.

### *Project Implementation*

An educational intervention was provided to the CRNA staff on October 4, 2023. The educational intervention encouraged the CRNA staff to utilize QNM when caring for patients receiving general anesthesia and neuromuscular blocking drugs. The presentation included the following topics: proper usage of AMG and EMG quantitative neuromuscular monitors, pharmacological differences between neostigmine and sugammadex, the shortcomings of subjective neuromuscular monitoring, high-risk patient populations, and the statistical patient safety benefits of using QNM (Appendix D).

### *Resources*

The PI will be the sole provider of financial support for the project. With that said, the hospital has already purchased the quantitative monitoring devices, so there is no cost involved in obtaining the proper equipment. Planned expenses necessary for this project are as follows: the gift card purchased to incentivize participation, breakfast for the staff on the day of the educational intervention, and gas for commuting to and from the facility. The total budget for the project was $150.

### *Data Collection*

First, the PI used a pre- and post-educational intervention survey to measure knowledge, perceptions of QNM, and existing barriers to using QNM. The survey was given to the CRNA staff immediately before the educational intervention. To account for the staff that were absent on the day of the educational intervention, the educational material and the survey were emailed to the entire CRNA staff list. Instructions to complete the online survey before viewing the material were provided. The same survey was sent to the CRNA staff by email one month after the intervention.

Secondly, deidentified patient information was obtained to measure an increase in the usage of QNM by examining PACU times. EPIC personnel helped gain access to deidentified patient records. All laparoscopic surgical cases that met the inclusion criteria 30 days before the education, were examined. After the educational intervention, all surgical cases that met the inclusion criteria and occurred within 30 days following the intervention were also assessed. Total time spent in the PACU following surgery was the primary patient outcome analyzed for this project due to limitations with data collection.

The inclusion criteria for the cases reviewed are as follows: patients eighteen years or older, receiving general anesthesia with an endotracheal tube, a laparoscopic procedure, a surgical case requiring the administration of nondepolarizing neuromuscular blocking drugs (rocuronium or vecuronium), and extubation planned at the end of the case in the operating room. The following criteria excluded a patient's case from being reviewed: patients younger than eighteen years old, patients who remained intubated after the case, and cases that required an endotracheal tube without nondepolarizing neuromuscular drugs. Informed consent was unnecessary for this project because the patient data was de-identified.

The pre-and post-survey used a 7-point Likert scale. Answers to questions ranged from one to seven (1 – strongly disagree, 2 – disagree, 3 – somewhat disagree, 4 – neither agree nor disagree, 5 – somewhat agree, 6 – agree, 7 – strongly agree). Perceptions of QNM and barriers to using QNM were measured with the pre-and post-survey. The Likert scale has traditionally been used to measure attitudes toward an object or phenomenon; therefore, this specific type of scale was the appropriate choice for this project. Taherdoost (2019) reports that the reliability of the Likert scale is maximal when using a 7-point scale, and validity also increases with more scale points.

***Data Analysis***

During the data analysis process, the PI worked closely with the assigned DNP faculty mentor and a statistician at UNCG. Due to limitations in the EPIC software used for data collection, it was impossible to measure QNM usage before or after the educational intervention directly. For this project, QNM usage was indirectly measured by examining the length of stay in the recovery room. This data analysis process entailed a two-sample F-test in Excel to determine equal or unequal variances. A two-sample t-test was then conducted, assuming equal variances.

The data gathered from the pre-and post-intervention surveys was analyzed using percentage bar charts. Survey questions were grouped to represent each category to measure CRNA perceptions, knowledge, and barriers. Questions 4, 5, 6, 8, 9, 10, 11, and 16 were selected to represent CRNA perceptions; question 12 was selected to represent CRNA knowledge; question 13 was chosen to represent CRNA comfort level with QNM; and questions 7, 14, and 15 were selected to evaluate barriers to the use of QNM. To simplify the bar charts and make them easier to interpret, the data obtained from a 7-point Likert scale was reduced to a 3-point Likert scale. Survey responses such as strongly agree, agree, and somewhat agree were grouped into one category titled "agree". Survey responses such as strongly disagree, disagree, and somewhat disagree were grouped into one category titled "disagree". Survey responses of neither agree nor disagree were given the title "neutral". This project only produced 12 paired surveys, so a paired t-test was not a valid analysis tool. Excel was the primary tool used to analyze data. Statistical significance was determined to inform the PI whether the quality improvement initiative was successful or not.

**Results**

When the pre-intervention length of stay in the PACU was compared to the post-intervention length of stay in the PACU, there was a two-minute difference in average time. The pre-intervention patients (n=124) stayed in the recovery room for an average of 101 minutes. However, the post-intervention patients (n=145) remained in the recovery room for an average of 99 minutes. A two-sample F-test for variances produced a p-value of 0.06. Assuming equal variances, a two-sample t-test was performed. The test yielded a p-value of 0.81. This indicates that there was not a statistically significant difference in the length of stay in the PACU when comparing pre-intervention patient records to post-intervention patient records.

For this project, 40 pre-intervention surveys were completed, but only 12 post-intervention surveys were completed. Based on pre-intervention survey data, 13% of CRNAs reported they always/frequently used QNM, and 74% of CRNAs said they rarely/never used QNM. Post-intervention survey results revealed that 0% of CRNAs report always/frequently using QNM, and 80% of CRNAs report rarely/never using QNM (See Appendix C, Figure 1). Based on these results, the usage of QNM decreased after the educational intervention.

Next, survey responses revealed CRNA knowledge of QNM remained relatively high. 64% of CRNAs claimed to have knowledge of QNM on pre-intervention surveys and 67% claimed to have knowledge of QNM on post-intervention surveys (See Appendix C, Figure 2). There was a 10% increase in CRNAs who claimed they were less comfortable using QNM than a PNS (See Appendix C, Figure 3). Further data revealed no improvement in CRNA perceptions of QNM when comparing pre-intervention and post-intervention responses. 60% of CRNAs answered that they have positive perceptions of QNM on pre-intervention surveys and 58% of CRNAs responded that they have positive perceptions of QNM on post-intervention surveys (See

Appendix C, Figure 4). Lastly, the most significant change in survey responses came when CRNAs were asked about existing barriers to the use of QNM. On pre-intervention surveys, 46% of CRNAs agreed there were specific barriers to using QNM. However, 69% of CRNAs agreed there were existing barriers to using QNM on post-intervention surveys (See Appendix C, Figure 5). With these increased perceived barriers, the educational intervention successfully shed light on existing obstacles hindering CRNAs from using QNM routinely.

## Limitations

The EPIC data analysis tool could not specify which patients received care with QNM. If this had been possible, this project would have had more precision and validity. Instead, QNM usage was indirectly assessed by comparing the length of stay in the PACU between the two groups. Another weakness in this project was the lack of CRNA participation in the post-intervention surveys. The goal was to produce results that would be statistically significant using a paired t-test. Paired t-tests with less than 30 paired surveys (n=30) cannot produce statistically significant results. This project yielded only 12 paired surveys (n=12).

## Discussion

Current literature reveals that using QNM reduces the length of stay in the PACU. Considering this information, the PI would expect to see a statistically significant decrease in PACU times following the educational intervention if the usage of QNM was adopted by anesthesia staff at the facility. However, data gathered from chart reviews showed no statistically significant decrease in PACU times when comparing pre-intervention to post-intervention. Therefore, the evidence shows this quality improvement initiative was unsuccessful in increasing the usage of QNM. Recommendations adopted from the 2023 ASA guidelines were given to the site to further facilitate the transition to more frequent usage of QNM (See Appendix B).

Survey responses showed that this quality improvement project did not increase CRNA knowledge/comfort level with QNM or improve CRNA perceptions related to QNM. However, based on the survey responses, CRNAs agreed substantial barriers are preventing them from using QNM routinely. Despite most CRNAs claiming to be comfortable using QNM, they still do not use the monitors. One of the significant barriers identified is not having access to the arms during a case. Most CRNAs agreed they would not use QNM when a procedure requires arms to be tucked. Lack of mobility only presents a problem when using acceleromyography monitoring. The CRNAs at this facility also have access to electromyography monitoring which does not require free range of mobility for accurate data to be gathered. More in-depth education on the difference between the two types of monitoring could increase the usage of QNM even when arms are tucked for various procedures. Another identified barrier was time constraints in the OR. According to survey data, CRNAs feel rushed to get cases started, so applying QNM before induction gets overlooked. The culture in the OR should revolve around patient safety, and CRNAs should never feel rushed to the point where patient safety could be compromised. To combat this barrier, having workstations for CRNAs to practice applying these monitors would be helpful. This would increase provider confidence while decreasing the time spent applying QNM in a fast-paced OR.

## Conclusion

There is a correlation between rNMB and postoperative respiratory complications, especially among the elderly and obese. It is critically vital that anesthesia providers adhere to the current recommendations of using quantitative neuromuscular blockade monitoring. Using these monitors can decrease the incidence of rNMB, increase patient safety, and decrease healthcare costs. Anesthesia providers should avoid dependence on subjective neuromuscular monitoring techniques and replace them with safer and more precise quantitative monitoring methods.

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**Appendix A: Pre/Post-Survey Tool**

| | |
|---|---|
| 1. How long have you been providing anesthesia as a certified registered nurse anesthetist: | < 1 year ☐ 1-5 years ☐<br>5-15 years ☐ > 15 years ☐ |
| 2. In the LAST MONTH, how often did you administer general anesthesia with neuromuscular blockade? | Daily ☐ 2-3x Weekly ☐<br>2-3x Monthly ☐ Never ☐ |

| **Please select what is most applicable to your experience/practice with the use of Quantitative Neuromuscular Monitoring.** | **Never** | **Rarely** | **Occasionally** | **Frequently** | **Always** |
|---|---|---|---|---|---|
| 3. I have incorporated the use of quantitative neuromuscular monitoring into my anesthesia practice. | | | | | |

| **Please indicate your perception of the ability of quantitative neuromuscular monitoring to improve patient outcomes by <u>reducing</u> the incidents of:** | **Strongly Disagree** | **Disagree** | **Somewhat Disagree** | **Neither Agree nor Disagree** | **Somewhat Agree** | **Agree** | **Strongly Agree** |
|---|---|---|---|---|---|---|---|
| 4. Post-operative Residual Neuromuscular Blockade | | | | | | | |
| 5. Increased Length of Stay in PACU | | | | | | | |
| 6. Post-operative Respiratory Complications | | | | | | | |
| **Which of the following best describes your attitude towards quantitative neuromuscular monitoring** | **Strongly Disagree** | **Disagree** | **Somewhat Disagree** | **Neither Agree nor Disagree** | **Somewhat Agree** | **Agree** | **Strongly Agree** |
| 7. Time constraints in the OR prevent me from applying and using quantitative neuromuscular monitors. | | | | | | | |
| 8. Data obtained from quantitative neuromuscular monitors is usually accurate. | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9. Quantitative neuromuscular monitors are helpful for anesthesia providers regardless of their level of clinical experience. | | | | | | | |
| 10. Quantitative neuromuscular monitors should be used for every patient regardless of ASA score. | | | | | | | |
| 11. I trust data obtained from quantitative neuromuscular monitors more than I trust my own clinical judgment. | | | | | | | |
| 12. I am familiar with the use of quantitative neuromuscular monitors. | | | | | | | |
| 13. I feel more comfortable using QNM than a peripheral nerve stimulator when monitoring neuromuscular blockade. | | | | | | | |
| 14. I would only use quantitative neuromuscular monitors when I can access the arms during a case. | | | | | | | |
| 15. If my peers used quantitative neuromuscular monitors, I would also be more likely to use them. | | | | | | | |
| 16. Quantitative neuromuscular monitoring should be used even when sugammadex is given for antagonism. | | | | | | | |

**Appendix B: Practice Recommendations for the Project Site**

| **Anesthesia Practice Recommendations for Monitoring Neuromuscular Blockade:**<br>Adopted from the *2023 ASA Guidelines for Monitoring and Antagonism of Neuromuscular Blockade* (Thilen et al., 2023) |
| --- |
| **1.** When administering neuromuscular blocking drugs, anesthesia providers should not use clinical assessment alone to monitor neuromuscular blockade. Clinical assessment is subjective and results in residual neuromuscular blockade. |
| **2.** The use of quantitative neuromuscular monitoring is recommended over qualitative neuromuscular monitoring (PNS, clinical assessment, etc.) to avoid residual neuromuscular blockade. |
| **3.** Anesthesia providers are recommended to confirm a TOFr > 0.9 with quantitative neuromuscular monitoring before tracheal extubation. |
| **4.** Anesthesia providers are recommended to use the adductor pollicis muscle for neuromuscular monitoring. |
| **5.** Anesthesia providers are recommended against using the orbicularis oculi muscle for neuromuscular monitoring. |
| **6.** To avoid residual neuromuscular blockade, anesthesia providers are recommended to use sugammadex over neostigmine to antagonize deep, moderate, and shallow neuromuscular blockade. |
| **7.** The use of neostigmine is only recommended at minimal depth of neuromuscular blockade (TOFc of 4; TOFr of 0.4 to less than 0.9). |
| **8.** To avoid residual neuromuscular blockade when administering atracurium or cisatracurium and using qualitative monitoring, neostigmine should be used for antagonism at minimal neuromuscular blockade. Further, the provider should allow 10 minutes to pass from antagonism to extubation when using qualitative monitoring. When quantitative monitors are used, extubation is permitted when TOFr ≥ 0.9. |

**Appendix C: Percentage Bar Charts (Figures 1-4)**

**Figure 1**

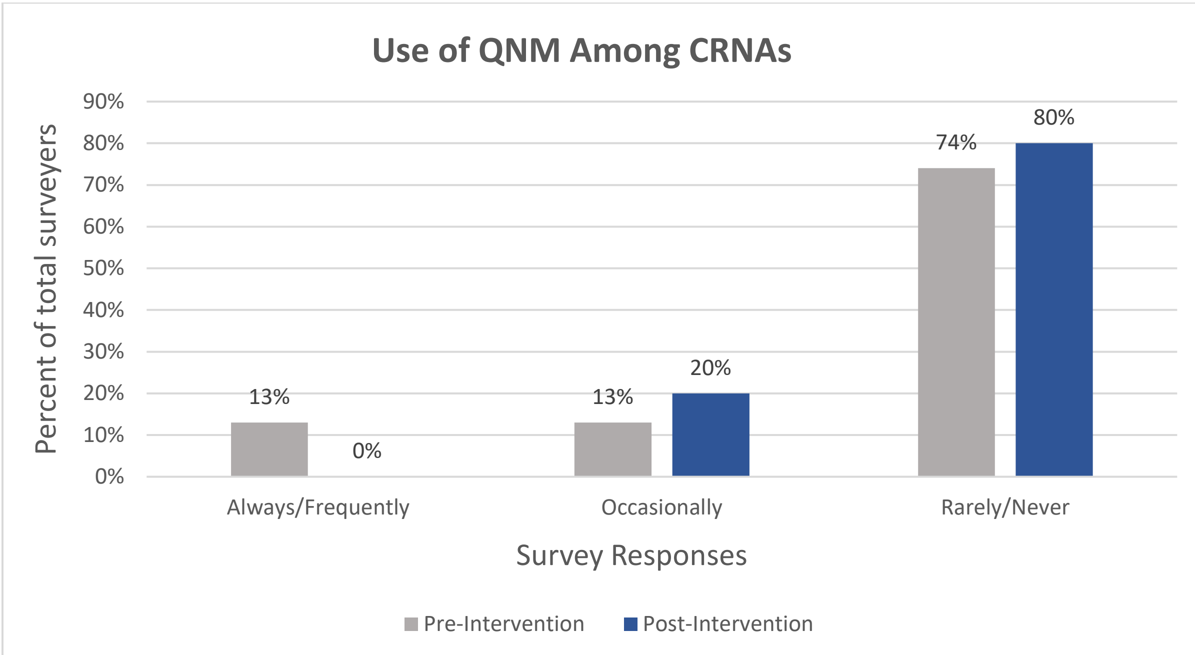



**Figure 2**

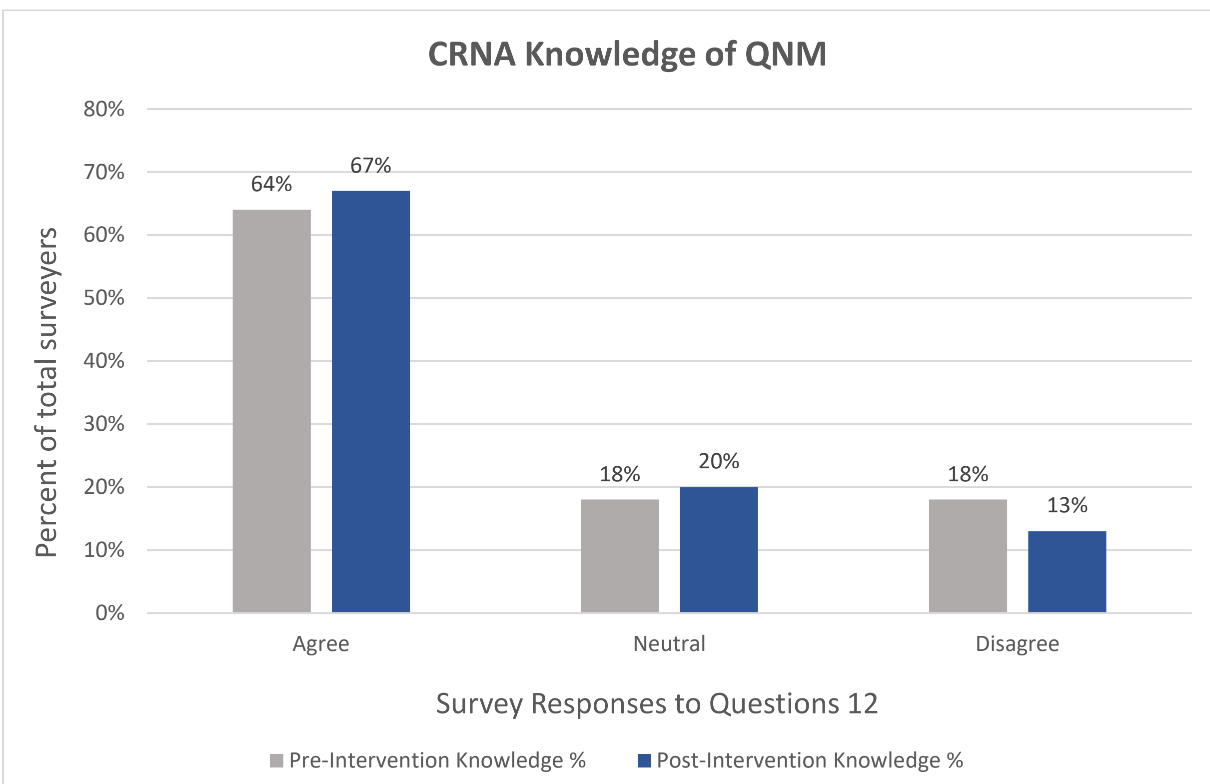


**Figure 3**

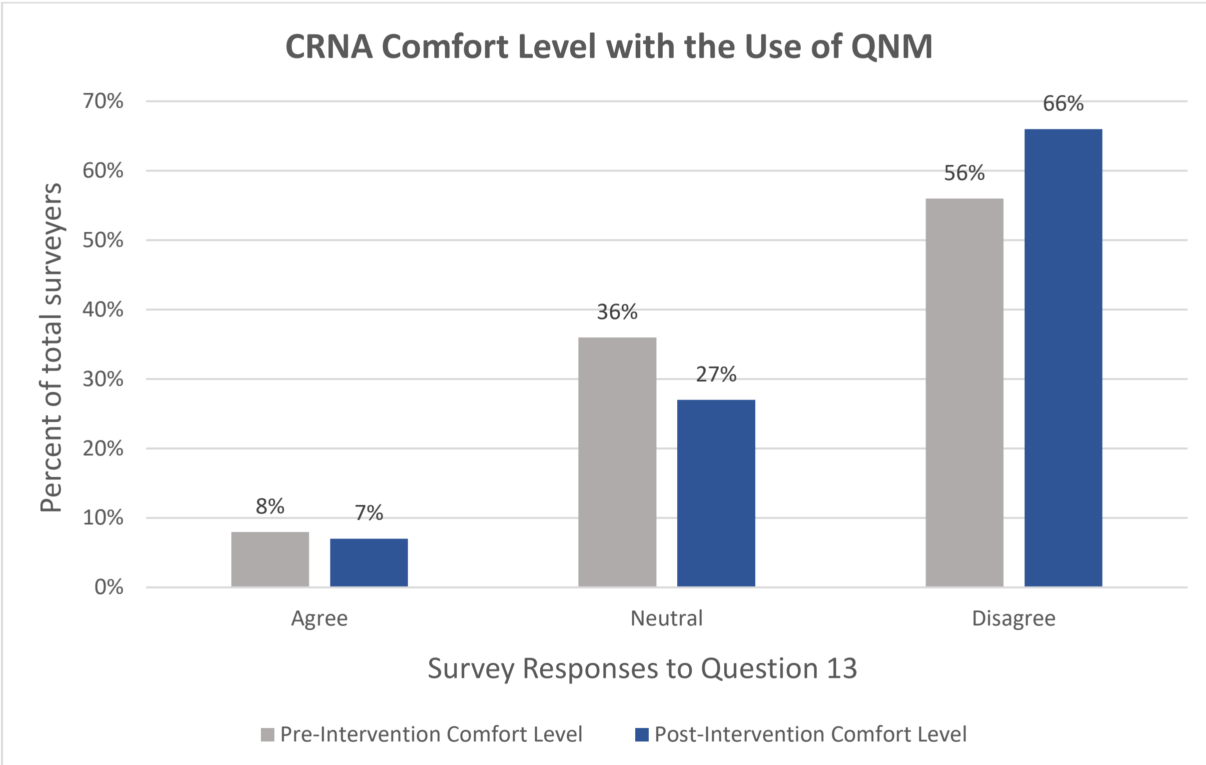



**Figure 4**

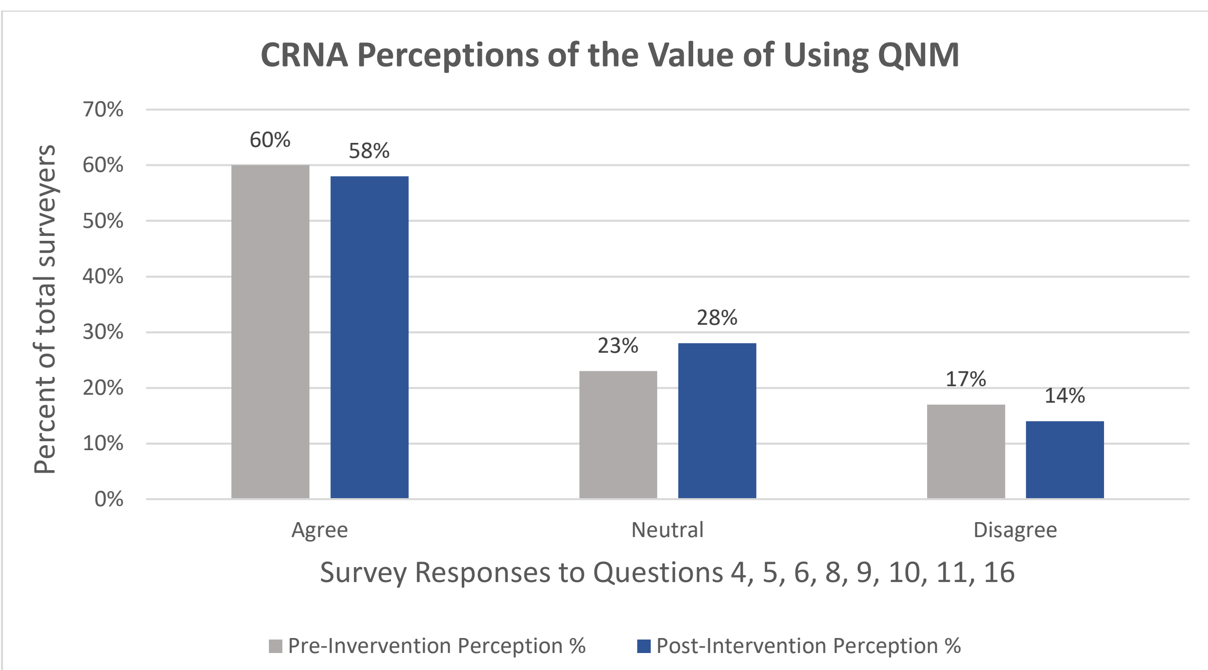
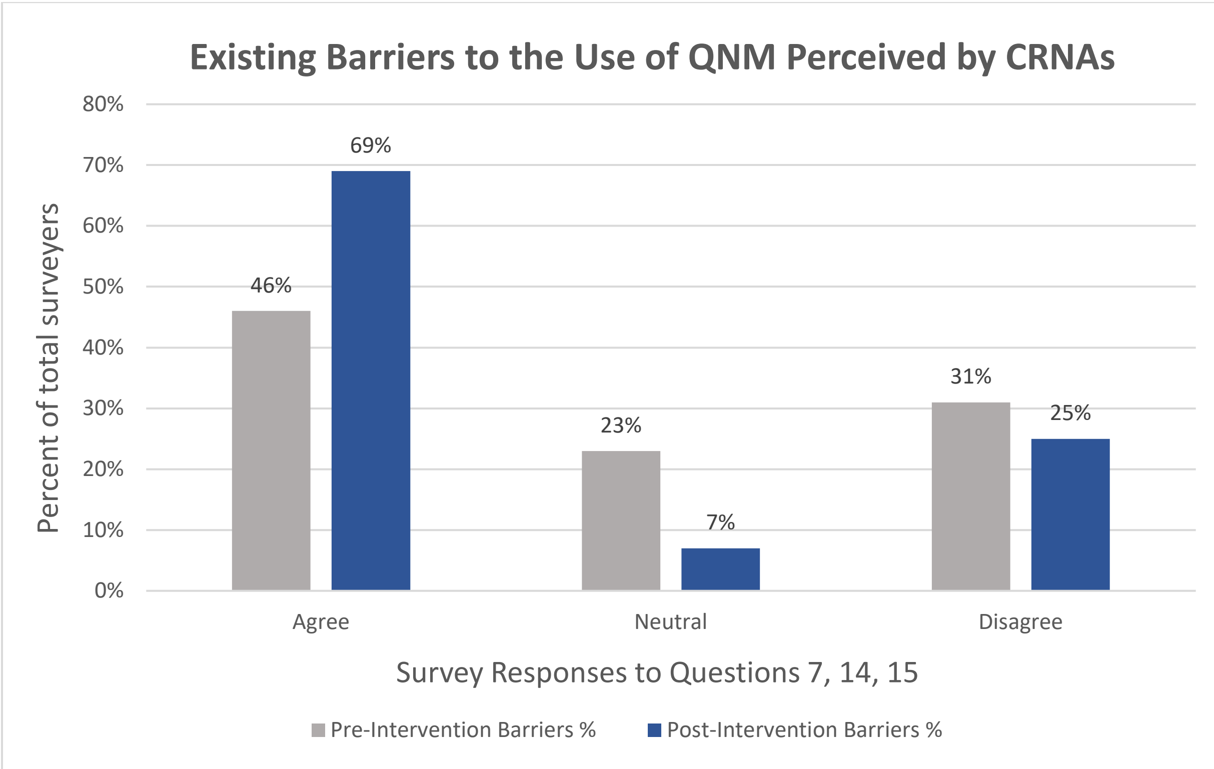
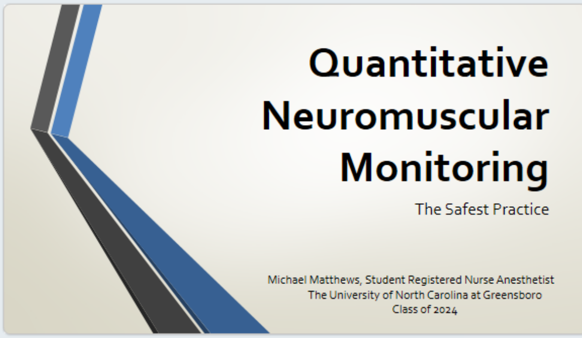


**Figure 5**


Existing Barriers to the Use of QNM Perceived by CRNAs
Percent of total surveyers
80%
70%
60%
50%
40%
30%
20%
10%
0%
69%
46%
23%
7%
31%
25%
Agree
Neutral
Disagree
Survey Responses to Questions 7, 14, 15
Pre-Intervention Barriers %
Post-Intervention Barriers %

## Appendix D: PowerPoint Presentation

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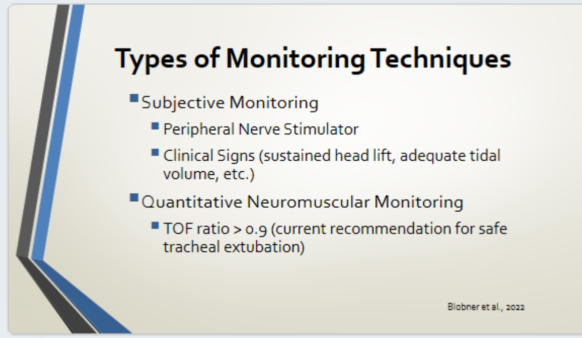


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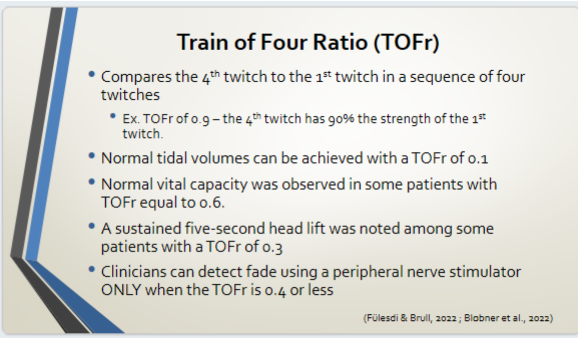


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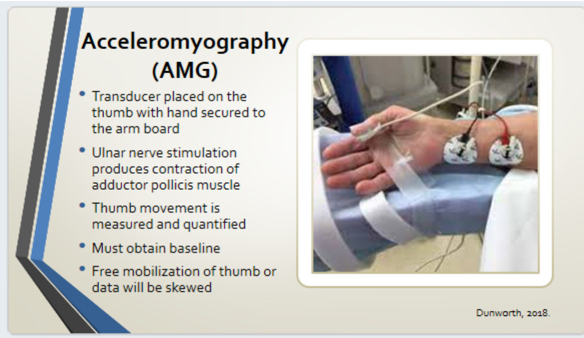


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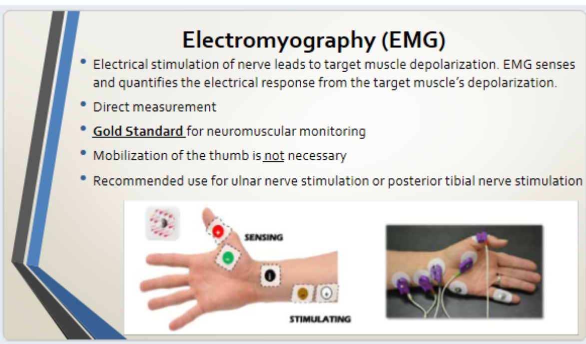


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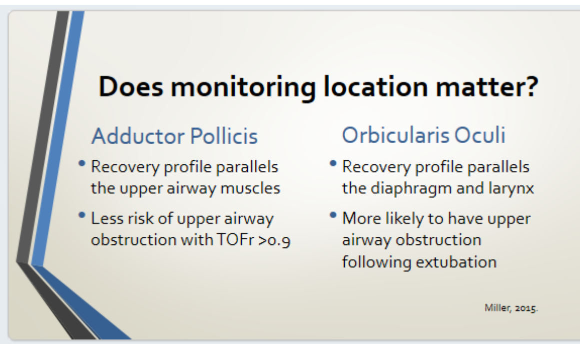


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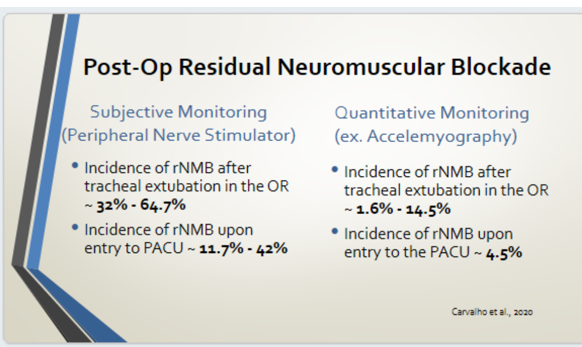


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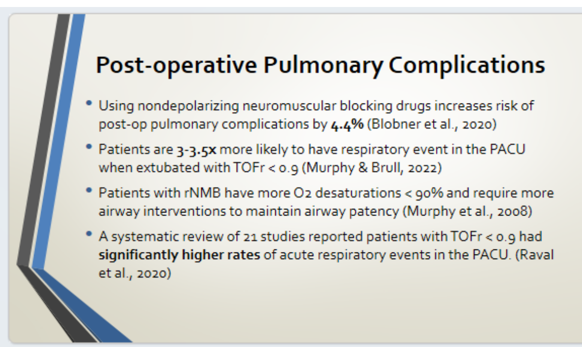


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## Neostigmine

**Drug Class:** Acetylcholinesterase Inhibitor

- **Downfall**: This drug has a ceiling effect.
  - The amount of acetylcholine that can be produced is not infinite.
  - Therefore, it cannot reliably reverse profound or deep neuromuscular blockade
- Onset: 5 – 15 minutes

- Results from a systematic review by Raval and colleagues (2020)
  - After an appropriate dose of neostigmine for moderate NMB (TOFc 1-3), residual NMB was observed:
    - In 100% of patients after 2 minutes
    - In 82% of patients after 6 minutes
    - In 39% of patients after 15 minutes
    - In 14% of patients after 60 minutes

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## Neostigmine Dosing Chart

| Neuromuscular Blockade (NMB) | Reversal Drug with Dose |
|---|---|
| TOFr ≥ 0.9 | Neostigmine 30-40 mcg/kg or Reversal not necessary |
| Shallow NMB → 4 twitches present and TOFr < 0.9 | Neostigmine 60-70 mcg/kg IV (5 mg max) or Sugammadex 2 mg/kg |
| Moderate NMB → 2-3 twitches present | Sugammadex 2 mg/kg, Neostigmine NOT recommended |
| Deep NMB → 1 twitch present or 4 post-tetanic twitches | Sugammadex 4 mg/kg, Neostigmine NOT recommended |
| Profound NMB → Less than 4 post-tetanic twitches | Sugammadex 4-16 mg/kg, Neostigmine NOT recommended |

Nagelhout & Elisha, 2018

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## Summary of 2023 ASA Recommendations

1. Avoid using clinical assessment alone when assessing depth of neuromuscular blockade
2. The use of quantitative neuromuscular monitoring when using non-depolarizing neuromuscular blocking drugs
3. Confirm a TOFr ≥ 0.9 with quantitative neuromuscular monitoring prior to tracheal extubation
4. Monitoring of the adductor pollicis muscle as opposed to the orbicularis oculi muscle
5. Sugammadex should be used over neostigmine for deep, moderate, and shallow depths of NMB
6. Neostigmine should only be given for minimal NMB
7. When QNM is not utilized, allow at least 10 minutes to pass before extubation when using neostigmine to reverse minimal NMB

(Thilen et al., 2023)

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## Questions?

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