DNP Project Proposal Outline: Final Draft

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DNP Scholarly Project Final Approvals

The DNP student ANDREW WEATHERINGTON **and the Scholarly Project** INCREASING UNDERSTANDING AND UTILIZATION OF OBJECTIVE (QUANTATIVE) NEUROMUSCULAR MONITORS AMONGST ANESTHESIA PROVIDERS **meet all the requirements for the degree of Doctor of Nursing Practice at University of Saint Francis-Fort Wayne, IN.**

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Abstract

Problem Statement—Research has demonstrated that ensuring a train-of-four ratio (TOFR) > 0.9 with an objective neuromuscular monitor is the safest practice to prevent residual neuromuscular blockade (RNMB). Unfortunately, the traditional practice of subjective neuromuscular monitoring and clinical bedside tests has not reduced the incidence of RNMB from where it was in 1979. Marion General Hospital (MGH) in Marion, Indiana, has an objective neuromuscular monitor in every operating room. However, none of the anesthesia providers utilize the objective monitors due to a perception of inaccuracy and increased complexity. **Purpose**—The project aimed to increase the perceptions, understanding, and likelihood of using the objective neuromuscular monitor amongst anesthesia providers. **Method**—A pretest, educational intervention, and post-test were administered, followed by a hands-on demonstration of the objective neuromuscular monitors. The data was analyzed to find percentage change. **Results**—89% of pre-and post-intervention providers believed RNMB to be a significant clinical problem. Two-thirds (67%) of anesthesia providers "always" monitor neuromuscular function using subjective or objective monitoring. There was an 11% decrease (78% to 67%) following the intervention in participants' belief that objective neuromuscular monitors would reduce RNMB. **Implications**— As EMG technology becomes more portable and user-friendly, more anesthesia department heads will likely purchase these devices. New EMG monitors such as the TwitchView® Train of Four Monitor could be an objective monitor able to overcome these barriers in practice. Keywords used as search terms were *residual curarization, residual neuromuscular blockade, postoperative pulmonary complications, critical respiratory events, quantitative neuromuscular monitors, and peripheral nerve stimulators.*

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Chapter 1: Introduction

Residual Neuromuscular Blockade (RNMB)

The purpose of this review is to highlight the gaps in clinical practice as it pertains to neuromuscular blockade management and the utilization of objective neuromuscular monitoring. Residual neuromuscular blockade (RNMB) is when the patient's neuromuscular function has not returned to baseline after the administration of neuromuscular blocking agents (NMBAs) prior to removing the artificial airway (endotracheal tube) via tracheal intubation. The existence of RNMB is demonstrated as a train-of-four ratio (TOFR) < 0.9 (less than 90% return to baseline) as measured at the adductor pollicis muscle of the thumb via the ulnar nerve before removal of the artificial airway or in the recovery room (Viby-Mogensen & Claudius, 2015). Greater than 90% return to baseline is important, as even at this ratio, up to 70% of the patient's muscle receptors are still paralyzed (Viby-Mogensen & Claudius, 2015).

The train-of-four setting of the subjective or objective monitor is the most commonly used electrical stimulation pattern to assess the degree of neuromuscular blockade, delivering four stimuli to the selected nerve at 2 Hz over two seconds (Hund et al., 2016). A train-of-four count (TOFC) is simply the number of muscle twitches visible to the eye or tactile to the hand when the train-of-four setting is used (Appendix A). A train-of-four ratio (TOFR) is the ratio of the fourth twitch's strength to the first twitch's strength (T_4/T_1) when the train-of-four setting is used (Thilen & Bhananker, 2016). A subjective monitor allows the clinician to count the number of muscle twitches present, estimating by vision or hand the strength of the present twitches. In contrast, an objective monitor using the train-of-four setting will calculate the number and strength of muscle twitches and provide a numerical value calculated as the train-of-four ratio (TOFR). As a result, the anesthesia provider estimates the train-of-four count by vision or hand when using a subjective monitor, while an objective monitor performs the calculation of the train-of-four ratio for the provider (Hund et al., 2016). Consequently, objective monitoring provides a more accurate assessment of the degree of neuromuscular blockade when compared to the eyes or hands of the clinician (Naguib et al., 2018).

Problem Statement

To date, research has demonstrated that ensuring a train-of-four ratio (TOFR) > 0.9 is the safest practice to prevent RNMB (Murphy & Brull, 2010; Plaud et al., 2010). However, subjective neuromuscular monitoring (peripheral nerve stimulator) and clinical bedside tests are currently the most common practice among anesthesia providers to monitor neuromuscular recovery and residual paralysis (DiMarco et al., 2010; Naguib et al., 2010; Thomsen et al., 2017). The utility of clinical tests in evaluating neuromuscular recovery has been unreliable and was initially developed to be used in primarily awake and cooperative patients (Brull & Kopman, 2017). The most commonly used settings on the peripheral nerve stimulator, "train-of-four count," cannot reliably detect a TOFR > 0.4 (greater than 40% return to patient’s baseline), and the "double burst stimulation" setting cannot reliably detect a TOFR > 0.6-0.8 (greater than 60-80% return to patient’s baseline) (Capron et al., 2006; Fruergaard et al., 1998; Naguib et al., 2018; Viby-Mogensen et al., 1985).

The traditional practice of subjective monitoring and neostigmine (an indirect paralysis reversal drug) administration has not reduced the incidence of RNMB from where it was in 1979 (Fortier et al., 2015). When the newer and more expensive reversal agent sugammadex is administered in combination with subjective monitoring, the incidence of RNMB and its consequences are reduced but not eliminated (Hristovska et al., 2017). Consequently, an objective neuromuscular monitor is required to obtain a train-of-four ratio which gives a numerical value (more accurate) versus a train-of-four count of the patient's observed muscle twitches. The patient could have the maximum of four perceived strong muscle twitches, yet, still have only a return of 50% of their neuromuscular function.

With objective neuromuscular monitoring, the monitor assess the degree of paralysis remaining. Whereas, subjective monitors elicit muscle twitch responses, but the anesthesia provider interprets the degree of paralysis remaining based on these responses. Therefore, with subjective monitoring, the degree of paralysis is determined by the eyes and hands of the anesthesia provider and leads to higher incidences of RNMB when compared to objective neuromuscular monitor interpretation. Still, some anesthesia providers do not use any monitoring of neuromuscular function and recovery. Recent surveys have demonstrated that subjective monitoring was used in only 40% of patients after administration of NMBAs, and objective monitoring was used in only 17% of patients after NMBAs administration (Thomsen et al., 2017).

Background of the Problem

Residual neuromuscular blockade (RNMB) is a consequence of neuromuscular blocking agents (NMBAs) used during general anesthesia for optimal surgical conditions (Brull & Kopman, 2017). The consequences of RNMB are well documented in the literature over the past twenty years and carry a significantly increased risk of morbidity and mortality for patients (Bulka et al., 2016; Cammu, 2020; Viby-Mogensen et al., 1979). Since 1979, when RNMB began to be defined and acknowledged in research and clinical anesthesia, its incidence had been noted to be 40-60% (Naguib, Kopman, & Ensor, 2007; Fortier et al., 2015). Pivotal studies such as the RECITE study (2015) have observed the incidence to be 56.5-63.5%. However, recent clinical guidelines from research and clinical experts on neuromuscular blockade management and the prevention of RNMB have not been widely adopted into practice. The most impactful intervention available to reduce the incidence of RNMB is a quantitative (objective) neuromuscular monitor, yet, its adoption into traditional practice has been slow (Murphy, 2020; Naguib et al., 2018).

Practice/Knowledge Gap/Needs Assessment

Marion General Hospital (MGH) in Marion, Indiana, has an objective neuromuscular monitor (GE M-NMT Mechanosensor by Datex-Ohmeda) in every operating room. These monitors use kinemyography (KMG) technology to measure the TOFR. KMG is reliable in managing neuromuscular blockade when used appropriately and has been demonstrated to be superior to bedside tests and subjective monitors in detecting a TOFR > 0.9 (Claudius & Viby-Mogensen, 2008; Salminen et al., 2016; Trager et al., 2006). However, none of the anesthesia providers utilize this objective monitor but instead depend on less reliable subjective measures of neuromuscular monitoring and recovery due to a perception of a lack of accuracy and increased complexity with the objective neuromuscular monitor. This information was obtained under observation and self-survey during a rotation March-April 2021 with the multiple anesthesia providers at Marion General Hospital.

DNP Project Overview

Scope of Project

“Increasing the Understanding and Utilization of Objective (Quantitative) Monitors Amongst Anesthesia Providers” project was a quality improvement project and was conducted using a demographic survey and pre-test survey (Appendix B) via a provided QR code, followed by an educational PowerPoint presentation (Appendix H), which subsequently followed a hands-on demonstration on the proper use of the objective monitor, followed by the post-test survey

(Appendix C) via a provided QR code. The project material, including an informed consent and disclosure form, was handed out in a packet prior to the educational presentation. A two-week trialing period of the objective neuromuscular monitor was planned, followed by a survey that evaluated the anesthesia providers' understanding and utilization of the monitor after trialing. However, the two-week trialing period had to be eliminated during the implementation phase due to the frequent changeover of contracted anesthesia staffing at MGH.

The educational presentation included the most recent literature on the incidence of RNMB, the consequences of RNMB, current practice standards, monitoring technologies, current practice patterns, and the benefits of objective monitoring. The entire length of the presentation was approximately 10 slides, and the hands-on demonstration of the monitor did occur afterwards. This DNP project compared current knowledge and attitudes, awareness of techniques, and practice patterns regarding neuromuscular monitoring in the intraoperative period before and after receiving an educational presentation and training on the use of objective neuromuscular monitors.

Stakeholders

The project manager and DNP Advisor, Dr. Keith Cotrell, as well as the anesthesiologists, certified nurse anesthetists (CRNA), and student nurse anesthetists (SRNA) at Marion General Hospital were key stakeholders. Additionally, Brandon Scott, MSN RN, the Surgical Services Director, and Tracy Livingston, BSN RN, the OR Manager were key stakeholders in the project. Operating room registered nurses and certified surgical technicians (CST’s) were also stakeholders in the project.

Budget and Resources

Cost

Project materials that required printed forms of paper and cost of a secure collection device for collection of informed consents costs $100. There was a cost of $92 for laminated prompts to remind the anesthesia providers to utilize the monitors during the two week trialing period. $150 was spent on gas for travel back and forth to the implementation site for implementation, support, and follow-up. There was a $400 expense for catered lunch after implementation of the individual educational interventions for all of the staff's participation in the facilitation of the project.

Description of Resources

The objective (quantitative) neuromuscular monitors have already been purchased by the organization and are in every operating room (OR). Therefore, no charges are affiliated with the acquisition or use of the monitors. Additionally, OR staff (RNs and CSTs) did not have to be trained to assist anesthesia providers with applying the objective neuromuscular monitors as the two-week trialing period did not occur as originally planned.

Process and Outcomes

General Timeline

The concept development of this project began in January 2021 with the creation of a comprehensive literature review. Once the literature review was completed, a synthesis of the literature was constructed. Subsequently, in March 2021, a gap analysis was performed at Marion General Hospital with an identified gap in current practice and best practice according to the literature. Training in research, ethics, and compliance was completed through the Collaborative Institutional Training Initiative (CITI Program) for human research in April 2021

(Appendix D). In May 2021, an organizational assessment, strengths, weakness, opportunities, and threats (SWOT) analysis, and Force Field Analysis was conducted at Marion General Hospital as part of the planning phase.

In June 2021, an initial draft of the budget for the project was assembled following a meeting with the DNP practice advisor, practice mentor, and key stakeholders. Construction of the informed consent was finalized on July 10th, 2021. Marion General Hospital had given permission for implementation of the project in their operating rooms and did not require IRB submission through the hospital (Appendix D). The project timeline was to achieve Institutional Review Board (IRB) approval from the University of Saint Francis (USF) in November 2021. However, IRB approval (Appendix J.) from USF was completed in January 2022. Implementation started on January 26, 2022, through March 3, 2022, to ensure adequate time for implementation. Following implementation, an analysis of the results were performed, but the sample size (9) was too small for statistical analysis. The executive summary was completed in May 2022 and the dissemination of the results in June 2022. The project manager disseminated the results of the project using a PowerPoint presentation to the USF faculty and DNP Advisors. An abstract of the project's results were disseminated to the other stakeholders upon request. The Project Timeline summarized the project activities and dates of the project.

Setting and Target Population

The project site is a 99-bed not for profit community hospital in Grant County, Indiana. Marion General Hospital (MGH) is accredited by the Accreditation Commission for Healthcare (ACHC) which represents quality and excellence-of-care. MGH is also a Magnet Recognized organization which provides general, orthopedic, obstetrics, ear, nose, and throat, and urological surgical services to the community with an operating room capacity of seven OR's. The operating room schedules average 15-25 surgeries on a given day.

Participant Inclusion/Exclusion Criteria

A convenience sample of eight certified registered nurse anesthetists (CRNA) and one student registered nurse anesthetists (SRNA) constituted the sample of nine clinicians. There are eight anesthesia providers in the anesthesia department and one SRNA at any given time during the day. Contracted anesthesia providers made it possible to reach the sample goal of eight, but this also made it impossible to carry out the two-week trialing period. The contracted providers were present a day or a week at a time, making the trialing period unfeasible.

What the Participants are Expected to do

The participants signed the informed consent (Appendix F), a physical form of paper handed out to them within a packet by the project manager. In a modified implementation plan, anesthesia providers were presented with the educational intervention in a one-on-one setting in order to obtain informed consent and administer the demographic survey, pretest, intervention, and post-test. The participants took less than five minutes to complete the demographic survey and pretest (Appendix B). The educational intervention was a PowerPoint presentation (Appendix H) in a paper form consisting of approximately ten slides. Afterward, the participants completed a post-test which required less than five minutes. The project manager gave the hands-on demonstration in the operating room during actual surgeries and carried the objective neuromuscular monitor for the entirety of the day and utilized it in surgeries where NMBAs were administered.

Length of Time Required From Participants

Less than five minutes were required to complete the demographic survey and pretest. The educational intervention required approximately 10-15 minutes to read through, and the post-test survey required less than five minutes to complete. The Chief CRNA, Doug Pruitt, and the project manager attempted to set up a time and a room that worked for the anesthesia department. However, given the presence of contracted anesthesia providers, it was not feasible to implement the educational intervention nor conduct the hands-on demonstration in a group. Therefore, the demographic survey, pretest, PowerPoint presentation, and post-test were presented individually to anesthesia providers. The hands-on demonstration was modified to take place every day as the project manager carried the objective neuromuscular monitor around for the entirety of the day and utilized it in surgeries where NMBAs were used while at the same time providing demonstration to the anesthesia provider.

Setting for Data Collection

Participants were individually presented with the educational intervention within MGH in various settings inside and outside the operating room, including the physician lounge. In addition, each participant was given a packet that included the informed consent and sheets of paper with QR codes that linked the participants to the demographic survey and pretest prior to the educational intervention. Once the educational intervention was complete, the participants scanned a QR code to complete the post-test. All completed surveys were collected and stored in Microsoft Forms.

Expected Outcomes

The expected outcomes of this quality improvement initiative was to increase the anesthesia providers awareness of RNMB and increase their understanding of objective neuromuscular monitors. The expected goal is that at least one anesthesia provider will utilize the monitor in practice routinely to reduce the incidence of RNMB. If none of the anesthesia providers were to utilize the monitor after the quality improvement initiative, the knowledge of the incidence and consequences of RNMB would have been explained.

Risk Analysis

Risk Analysis

The project manager has completed the Collaborative Institutional Training Initiative (CITI) program (April 2021) prior to project development (Appendix D). Participation in the DNP project was voluntary, anonymous, and informed consent (Appendix F) was obtained on the day of the educational intervention, prior to the demographic survey and pretest. All data was protected by encryption via Microsoft Forms© with password protection in order to protect participant confidentiality and prevent unauthorized user access. No immediate or long-term risks were posed to the participants as it pertained to the educational intervention. No monetary compensation was given for the participant’s participation other than a catered lunch after the implementation phase was completed. No intended deception or experimental procedures were undertaken.

Chapter 2: Synthesis of Supporting Evidence and Project Framework

Relevant Theory and Concepts

Frameworks/Models/Concepts/Theories

Conceptual Framework: Knowledge-to-Action

The Knowledge-to-Action (KTA) Framework is one of the most utilized frameworks for directing knowledge translation (KT) (Graham et al., 2006). Developed by Dr. Graham et al., KTA Framework is a planned action framework created from the fabric of systems or processes frameworks (Appendix I). KTA is a meta-analysis of thirty-one other planned action theories.

Such frameworks aim to break down the process of change into components, making change more manageable and influencing decisions and behaviors of a group. KTA situates people who produce knowledge (knowledge producers) and people who use knowledge (knowledge users) within a system that is highly adaptable, responsive, and dynamic (Crockett, 2017).

The KTA Framework Cycle has two components: Knowledge Creation (funneled in the middle) + Action Cycle (circled around the knowledge creation funnel). Similar to Rogers Theory of Diffusion, knowledge is permeable and boundaryless in a social system with the aim of adopting a new idea or changing behavior. Each phase that makes up the Action Cycle can incorporate a theory within itself, lending to its use as a meta-framework.

The Knowledge Cycle. Composed of three components that act as a funnel into the Action Cycle. The first component is Knowledge Inquiry, which constitutes primary research or first-generation knowledge. As primary research is generated, single studies of stronger and lower-level evidence add to the existing body of knowledge but do not necessarily mean it is ready for translation into practice (Crockett, 2017). The second component is Knowledge Synthesis, which is second-generation knowledge or the synthesis of a body of knowledge that may lend itself to generalizability in practice. Systematic Reviews (SR) and Meta-Analysis (MA) constitute second-generation knowledge, where the results of a body of high-quality studies can be the impetus of a change in practice. The third component is Knowledge Tools/Products, or the third generation of knowledge, which has been refined and taken up into policy or practice. Examples are clinical practice guidelines or replication of evidence from SR and MA, and this becomes the knowledge that would be funnel into the Action Cycle.

Primary research undertaken has demonstrated that patient safety is enhanced when neuromuscular monitoring is utilized after administration of NMBA's (Asztalos et al., 2017;

Kotake et al., 2014; Le Corre et al., 2011). Multiple randomized controlled trials (RCT), MA's, SR's, and the Anesthesia Patient Safety Foundation (APSF) have established that a train-of-four ratio (TOFR) > 0.9 is required to reduce RNMB; however, a TOFR > 0.9 can only be detected by the use of a quantitative (objective) neuromuscular monitor (Brull & Kopman, 2018; Murphy et al., 2008, 2011, 2020; Naguib et al., 2018). Consequently, Knowledge Inquiry and Knowledge Synthesis have been established, and Knowledge Tools (clinical practice guidelines) have been set forth by organizations such as APSF and International Anesthesia Research Society (IARS), ready to be translated into clinical practice.

The Action Cycle. The Action Cycle traditionally starts with identifying a problem; however, the knowledge funnel can begin at any of the phases within the Action Cycle (Graham et al., 2006). Identifying a problem generally refers to comparing what the current practice is, compared to what it should be, leading to identifying a gap that should be closed in clinical practice (Kitson & Strauss, 2011)."Adapt knowledge to local context" incorporates phase two of the Action Cycle and makes reference to adapting knowledge to the specific area, institution, or organization the clinician finds themselves in, as well as the available resources. Harrison et al. (2013) found that adaptation is more about engagement and capacity building than the actual adoption of the proposed translation of evidence, highlighting essential skills such as communication and the ability to establish buy-in.

"Identifying Barriers and Supports to Knowledge Use" is the third phase of the Action Cycle and refers to identifying potential barriers and facilitators to implementing knowledge. "Selecting interventions or implementation strategies" is very difficult when the barriers to implementation are not first addressed and represent phase four of the Action Cycle. "Monitoring Knowledge Use" represents phase five, where the uptake of the evidence is being monitored, and the "Evaluation of Outcomes" represents phase six, where the impact of evidence being implemented is evaluated. Lastly, phase seven, "Sustained Knowledge Use," represents recommendations or interventions undertaken to sustain this new behavior in clinical practice.

Marion General Hospital in Marion, Indiana, is one of few institutions across the country that have quantitative (objective) neuromuscular monitoring in most of their operating rooms (OR). Within the KTA Action Cycle of "adapt knowledge to local context" (phase two), the available resources of objective monitors are readily available. However, the barriers to their implementation and use must be assessed before educational interventions and initiatives can be employed; thereby, addressing phase three of the KTA Action Cycle "assess barriers to knowledge use." All perceived barriers have been identified using interviews, observations, and review of records; therefore, educational interventions and initiatives are ready for implementation, fulfilling the "select and tailor implementation strategies" of the KTA Action Cycle. Once the educational interventions are implemented, a "monitoring of knowledge use" will occur, followed by an "evaluation of outcomes."

Theory: Lewin's Theory of Change

The barriers to implementation and use of quantitative (objective) monitors have been documented in the literature. Since the 1980s, objective monitors have been available for clinical practice using acceleromyography (AMG) technology (Viby-Mogensen et al., 1988). However, the use of bedside tests and peripheral nerve stimulator (subjective) monitors had already taken hold as the pillars of neuromuscular management in anesthesia (Nemes & Renew, 2020). Multiple anesthesia practice surveys have found wide variability in anesthesia provider's management of neuromuscular blockade (Di Marco et al., 2010; Kotake et al., 2014; Naguib et al., 2010, 2018). Consequently, forty years after the first commercially available objective monitors, resistance to a change in practice has become the primary hurdle to the implementation of these monitors for a multitude of reasons (Naguib et al., 2018). However, there have been surveys and literature documenting the additional time consumption, inconsistent readings, and lack of suitable alternatives when the thumb is not readily available with AMG and kinemyography (KMG) objective monitors (Hund et al., 2016; Oh et al., 2020; Soderstrom et al., 2017).

When examining "assessing barriers to knowledge use" and "selecting and tailoring implementation interventions" of the KTA Action Cycle, the utilization of Lewin's Theory of Change: Force Field Model can help move the project through these two critical phases. Lewin's Change Theory was grounded in his passion for understanding how social groups were formed, interacted, and maintained using his Group Dynamics and Field Theory (Back, 1992; Burnes, 2004; Kritsonis, 2005). However, to change social groups' behavior, Lewin developed what he called Action Research and the Three-Step Model of Change (Burns, 2004).

Lewin hypothesized that group behavior was influenced by a dynamic balance of forces that constantly worked in opposition to each other. The driving forces for change must overcome the restraining forces for the status quo to progress through the three stages of change (unfreeze, change, and refreeze) (Burnes, 2004). The status quo is maintained by the restraining forces or group behavior, which also affects individual decisions and behaviors. Todd et al. (2014) found the utilization of objective monitoring reached nearly 100% when there was a strong departmental champion and mentor facilitating the implementation strategies towards this endpoint, but the effort took nearly two years. The above example demonstrates how the strengthening of driving forces or diminishment of restraining forces, especially when stakeholders are supportive, can move the group's behavior towards new change.

The intent of this project is to "unfreeze" the status quo or traditional practice by creating an awareness of the most recent knowledge synthesis in the area of neuromuscular blockade management. Once the clinicians are aware of the most recent clinical guidelines, a transition or "change" can begin to take place by implementing the educational interventions. The stage of "change" is a process that will require education, communication, and support, as it is usually a time of uncertainty for those involved in the process (Shirley, 2013). Consequently, if the project is successful, Lewin declares "refreezing" can reinforce and solidify the new norm or change followed by continued efforts to sustain this new norm.

Literature Review

A literature search was initially conducted using the Cochran Database of Systematic Reviews Library, followed by MEDLINE with Full Text, CINAHL, and PubMed. The majority of articles were found using anesthesia journals and references within relevant articles. Journals such as *Anesthesiology, Anesthesia & Analgesia*, *European Journal of Anesthesiology, Canadian Journal of Anesthesia, Journal of Medical Systems, Current Anesthesiology Reports,* and *American Association of Nurse Anesthetists,* but this list is by no means exhaustive. Literature and clinical guidelines from professional societies such as the Anesthesia Patient Safety Foundation (APSF), International Anesthesia Research Society (IARS), American Association of Nurse Anesthetists (AANA), and American Society of Anesthesiologists (ASA) were searched. Foundational anesthesia textbooks and relevant clinical conferences were also searched. Keywords used as search terms were *residual curarization, residual neuromuscular blockade, postoperative recurarization, postoperative pulmonary complications, critical respiratory events, neostigmine, sugammadex, qualitative neuromuscular monitors, quantitative neuromuscular monitors, and peripheral nerve stimulators.*

Incidence

Researchers have come to refer to the phenomenon of RNMB as the "hidden universality of residual neuromuscular blockade," given its pervasive incidence yet, hidden existence in the thoughts of many anesthesia clinicians (Eikermann, 2016; Todd et al., 2014; Viby-Mogensen et al., 1979). In 2010, a survey of European and American anesthesia providers revealed that 64.1% of European and 52.2% of American clinicians believed the clinically significant incidence of RNMB to be < 1% (Naguib et al., 2010). Since Viby-Mogensen et al. (1979) exposure of RNMB as a consequence of NMBAs administration and their incomplete reversal, the incidence has remained relatively unchanged (Brueckmann et al., 2015; Fortier et al., 2015; Murphy et al., 2015; Sasaki et al., 2014). The RECITE Study (2015), a prospective observational study at eight hospitals in Canada, estimated the incidence of RNMB to be 63.5% at the time of removal of the artificial airway and 56.5% upon arrival to the recovery room. Additional researchers findings of the incidence of RNMB places it at 31- 40% when a quantitative (objective) monitor was used to measure the TOFR at the time of removal of the artificial airway and upon arrival in the recovery room (Debaene et al., 2003; Naguib et al., 2007; Todd et al., 2014).

Consequences

When a TOFR > 0.9 (greater than 90% of the patient's baseline) is not established before removing the artificial airway, the complications of RNMB are extensively supported in the literature (Cammu, 2020; Kopman, 2016). The consequences of RNMB from incomplete reversal of paralysis leaves the patient with a reduced ability to protect their airway leading to double vision, undesirable weakness after awakening, and an increased risk for critical respiratory events (CRE), or postoperative pulmonary complications (POPC or PPC) (Bulka et al., 2016; Cammu, 2020). The subsequent paragraphs will explain the different mechanisms through which residual paralysis places the patient at risk for CREs or POPCs.

Impaired Swallowing Muscles

Eating, drinking, and breathing require coordination of the pharyngeal and laryngeal muscles of the neck. When the pharyngeal constrictor muscles are impaired, the ability to swallow becomes dysfunctional. Likewise, when the laryngeal muscles become impaired, the ability to move air in and out of the lungs becomes dysfunctional. The impairment of either group of muscles puts the patient at an increased risk for adverse events in the recovery period (Herbstreit et al., 2009; Sundman et al., 2000). Swallowing is impaired at a TOFR 0.6-0.8, which is why a TOFR > 0.9 is the minimum standard to ensure a margin of safety for recovery (Eikermann et al., 2007; Herbstreit et al., 2009). Consequently, RNMB increases the risk of aspiration by 4-fold due to impaired swallowing and is a cause of aspiration pneumonia following surgery (Asai & Isono, 2014; Sundman et al., 2000). However, recent research has suggested that a TOFR > 0.95 (95% of return to baseline) should become the threshold for adequate recovery, as impaired oxygen responsiveness has been noted even at a TOFR 0.90-0.95 (Blobner et al., 2020).

Impaired Breathing Muscles

The diaphragm and the laryngeal muscles are the most resistant to NMBA-induced paralysis. At a TOFR 0.4-0.5 (40-50% of return to patient's baseline), the depth and frequency of the patient's breaths are still adequate, and the opening and closure of the larynx are still functional. The pharyngeal muscles are not only responsible for swallowing but are also referred to as the upper airway dilator muscles. While the diaphragm is still functional and the larynx is still able to open and close appropriately at a TOFR 0.4-0.5, breathing is impaired when the pharyngeal dilator muscles do not move the tongue forward and elevate the soft palate (Mirzakhani et al., 2013; Sundman et al., 2000). Consequently, when these dilator muscles are impaired by residual paralysis, the upper portion of the airway collapses onto itself, impeding air movement (Eikermann et al., 2007; Herbstreit et al., 2009).

Impaired Response to Low Arterial Oxygen.

The arteries of the neck have oxygen sensors that measure the blood's oxygen levels as it leaves the heart and moves toward the brain. The location of these sensors allows the brain to make changes to the breathing rate and pattern in real-time to prevent oxygen deprivation to the brain (Iturriaga et al., 2016). The administration of NMBAs in even small amounts will impair these oxygen sensors from detecting low oxygen levels in the blood, thereby impairing the brain's ability to respond to this low oxygen event (Eriksson, 1996, 1999; Jonsson et al., 2004). Consequently, RNMB disables this correction mechanism, placing the patient at increased risk for brain injury (CRE) from low oxygen levels. Therefore, ensuring a TOFR > 0.9 (greater than 90% return of patient's baseline) increases the margin of safety for the patient. However, recent literature has demonstrated that a TOFR > 0.95-0.99 may be required, as this low oxygen mechanism can still be impaired at TOFR > 0.9 (Broens et al., 2019).

Prolonged Recovery Stay and Increased Costs

Arrival to the recovery room with residual paralysis has been found to prolong stays in recovery and increase the risk of admission to the intensive care unit (ICU) (Bulka et al., 2016; Butterly et al., 2010; Grabitz et al., 2019). The elderly are at significantly increased risk for RNMB, leading to higher frequencies in prolonged recovery stays and ICU admissions when compared to other populations exposed to RNMB (Hardemark Cedborg et al., 2014; Murphy et al., 2015). Delayed release from the recovery room postpones the cycle of throughput by causing a backlog in the operating room and recovery room, leading to increased costs (Butterly et al., 2010; Thevathasan et al., 2017). In-room and out-of-room time is critical to the efficiency and profitability of the operating room and recovery room. Grabitz et al. (2019) found that RNMB led to increased hospital length of stay and admission to the ICU, but costs were not significantly increased.

Vulnerable Populations

The presence of RNMB (TOFR 0.4-0.9) in young, healthy patients may not produce CREs and POPCs that follow impaired arterial oxygen sensors, impaired breathing, or swallowing muscles (Kopman et al., 1997). However, for many patients with specific demographics and pathological conditions, RNMB places them at significant risks for CREs and POPCs. One such group of patients is the elderly (> 65 years of age), the elderly have impaired weakening of respiratory muscles (loss of muscle tone) at baseline, which leads to impaired swallowing, coughing, and increased risk of aspiration (Strom et al., 2016). NMBAs have a prolonged duration of action in the elderly when there is not a dose reduction from normal ranges (Murphy et al., 2015). The incidence of RNMB is higher in the elderly when given NMBAs, which explains the increased incidence of hypoxic events, aspiration pneumonia, prolonged recovery room, and hospital stays following surgery (Murphy et al., 2015). Consequently, objective monitoring of neuromuscular blockade can significantly increase the margin of safety for the elderly by ensuring a TOFR > 0.9.

Patients with obesity, obstructive sleep apnea (OSA), pre-existing respiratory disease, and neuromuscular disease have impaired ventilation at baseline when performing activities of daily living and are at an increased risk for RNMB (Carron et al., 2012). Many of these patients already demonstrate the pathology that leads to CREs and POPCs, such as impaired respiratory response to low oxygen levels in the blood and weakened respiratory muscles (Guldner et al., 2013; Kumar et al., 2012). Generalized muscle weakness is an independent predictor of symptomatic aspiration and pharyngeal dysfunction in ICU patients (Mirzakhani et al., 2013). Obese (BMI > 30) patients have a decreased pharyngeal opening at baseline due to excess hypopharyngeal tissue. Obese patients also have a rapid, shallow breathing pattern due to the excess weight around the chest acting as a restriction (Bustamante & Bucklin, 2017). Consequently, there are populations of patients at significant risk of morbidity and mortality when exposed to incomplete reversal of paralysis and require objective monitoring to safely remove the artificial airway at the conclusion of surgery.

Reversal Drugs and RNMB

NMBAs are associated with CREs and POPCs without reversal, with inadequate reversal, without any neuromuscular monitoring, and with subjective neuromuscular monitoring (Mclean et al., 2015; Sasaki et al., 2014). There is a pervasive perception in clinical practice that a single dose of NMBA for intubation (placement of artificial airway) does not require reversal if 30-45 minutes has gone by since administration. Debaene et al. (2003) found that out of 239 patient's administered a single dose of NMBA for intubation, 37% of patients demonstrated a TOFR < 0.9 at least two hours after administration with no reversal. Consequently, when no reversal agents are used, the patient is at increased risk for postoperative pneumonia and respiratory failure (Bulka et al., 2016; McLean et al., 2015).

For more than 50 years, the workhorse for reversal of neuromuscular paralysis has been acetylcholinesterase inhibitors (AchE inhibitors) such as neostigmine (Brull & Kopman, 2017). AchE inhibitors act indirectly by preventing the breakdown of acetylcholine molecules at the neuromuscular junction (NMJ); thus, acetylcholine molecules are able to accumulate in large enough numbers to displace the NMBA molecules from the nicotinic receptor of the muscles. Acetylcholine (Ach) is the chemical transmitter of muscle activity in the body, and muscle activity is prevented if NMBAs occupy the nicotinic receptors. AchE inhibitors like neostigmine are imperfect reversal drugs with many side effects (bradycardia, nausea, vomiting, bronchoconstriction, etc.) since their actions are not specific to the neuromuscular junction where NMBAs attach (Brull & Kopman, 2017).

Brueckmann et al. (2015) found that 43% of patients reversed with neostigmine after NMBA administration had residual paralysis upon removing the artificial airway or upon arrival to the recovery room. Neostigmine cannot be used to reverse a deep or intense neuromuscular block where there are less than < 2 twitches from the train of four counts or a TOFR < 0.2, the clinician must wait until the patient's neuromuscular function has spontaneously recovered to a greater degree (Brull & Kopman, 2017; Kirkegaard et al., 2002). Consequently, neostigmine has not reduced the incidence of RNMB, has many undesirable side effects, and cannot be given until the patient has spontaneously recovered to a certain degree.

Until recently, there did not exist a drug that could directly prevent the actions of NMBAs. Sugammadex (cyclodextrin) is a newer reversal drug, which acts directly upon aminosteroidal based NMBAs (Hristovska et al., 2018). One molecule of sugammadex will encapsulate one molecule of aminosteroidal based NMBA and render it useless, eliminating the encapsulated NMBA in the urine (Hristovska et al., 2018). Given sugammadex's direct mechanism of action on NMBAs, it does not produce the side effects of neostigmine when indirectly blocking the actions of NMBAs (Hristovska et al., 2018). Sugammadex will reverse paralysis more quickly and predictably than neostigmine regardless of the degree of blockade

(1.8 minutes versus 22.7 minutes) during general anesthesia when using anesthetic gases (Carron et al., 2016; Kim et al., 2004).

Sugammadex's direct action makes it a superior reversal drug to neostigmine and has been shown to reduce the incidence of RNMB and the consequences that follow, such as CREs and POPCs (Brueckmann et al., 2015; Kheterpal et al., 2020). Cost is a prohibitive barrier to the widespread use of sugammadex, as a 200mg vial of sugammadex costs ~ $90. In contrast, a vial of neostigmine costs $35 and a vial of glycopyrrolate $30 for a combined cost of $65 versus $90 for sugammadex (Carron et al., 2016; Kopman & Brull, 2013). Both sugammadex and neostigmine failed to reduce the incidence of RNMB when both subjective and objective neuromuscular monitoring were not used; therefore, neuromuscular monitoring is required for dosing the reversal agents to ensure a TOFR > 0.9 (Kotake et al., 2013; Oh et al., 2020). Consequently, safe management of NMBA administration requires reversal agents and the guide of subjective neuromuscular monitoring at a minimum. However, objective neuromuscular monitoring provides for the safest management of NMBAs and is the only reliable method to determine the TOFR (Debaene et al., 2003; Stoelting et al., 2016).

Subjective Monitoring

Clinical bedside tests and a peripheral nerve stimulator (PNS) are considered subjective monitors. However, the anesthesia clinician is the monitor in both instances. The anesthesia clinician assesses the patient's ability to perform bedside tests such a 5-second head lift, 5second leg lift, 5-second handgrip strength, 5-second eye-opening, tidal volume, ability to smile, and tongue depressor test by biting and holding it in their teeth against resistance (Murphy et al., 2011; Naguib et al., 2018). Unfortunately, these tests were designed to be performed on someone who has not undergone general anesthesia but is rather cooperative and awake (Brull & Kopman, 2017). Cammu et al. (2006) demonstrated the unreliability of these tests as single tests or in combination.

However, Viby-Mogensen et al. (1979) demonstrated that some patients could have a TOFR < 0.5 (less than 50% of return to patient's baseline) and perform clinical bedside tests like the 5-second head lift and 5-second hand grips. Additionally, > 70% of patients with a TOFR < 0.70 (less than 70% of return to patient's baseline) were able to perform a 5-second head lift (Beemer & Rozental, 1986; Cammu et al., 2006; Pedersen et al., 1990). Consequently, the International Anesthesia Research Society (IARS) has put out a consensus statement advocating for the abandonment of these bedside tests and the utilization of objective neuromuscular monitors as the standard of care for neuromuscular blockade management (Naguib et al., 2018). The Anesthesia Patient Safety Foundation (APSF) has also adopted the position that objective monitoring is the standard of care in neuromuscular blockade management (Stoelting, 2016).

Peripheral nerve stimulators, also considered subjective monitors, are small portable devices that are easy to use and cost-effective for institutions and help to explain their widespread use in clinical practice despite their inability to detect a TOFR > 0.9 (> 90% of return to patient's baseline) (Nemes & Renew, 2020). In fact, none of the different patterns of neurostimulation of the PNS can detect a TOFR > 0.80 (> 80% of return to patient's baseline) when measured at the adductor pollicis muscle of the thumb (Capron et al., 2006; Fruergaard et al., 1998).

However, the most common practice when using a PNS is to use the facial muscles (orbicularis oculi or corrugator supercilii) rather than the hand muscles (adductor pollicis). The facial muscles are unreliable for use with a PNS or an objective monitor when measuring recovery from paralysis. The adductor pollicis muscle of the thumb best correlates with recovery of the most sensitive muscles to NMBA paralysis (McGrath & Hunter, 2006; Thilen et al., 2012). Additionally, using the facial muscles to assess recovery will lead to an overestimation of return of recovery, given that the facial muscles recover quicker than the adductor pollicis muscle (Donati, 2012). Therefore, in clinical practice, recovery from NMBA paralysis is currently being monitored from the least effective site when assessing for adequate recovery.

Moreover, the PNS only fulfills one of the two requirements that must be present to be considered a neuromuscular monitor (Brull & Kopman, 2017). First, a monitor must be able to deliver an electrical stimulus to a peripheral nerve evoking a muscle's response. Secondly, it must be able to analyze and interpret the response of the muscle to the electrical stimulation (Brull & Kopman, 2017). Therefore, a PNS does not meet the requirements to be considered a "monitor," given that the anesthesia clinician carries out the analysis and interpretation of the muscle's response by vision or touch. However, the human eye nor the human hand can detect the presence of fade (weakness in muscle twitches) once all four twitches have returned when using the train-of-four count (TOFC) pattern of the PNS (Viby-Mogensen et al., 1985; Pedersen et al., 1990). Consequently, all four twitches from the TOFC can be present and appear strong, but the actual TOFR be < 0.5 because the human eye and touch cannot discern the small degrees of fade that exist between a TOFR of 0.5-0.9 (Naguib et al., 2018).

Objective Monitoring

Given that the ability to detect a TOFR > 0.5 (> 50% of return to patient's baseline) is not reliably possible when using the most common neurostimulation pattern of the PNS, quantitative (objective) monitors are now advocated for in the literature. Objective monitors meet the two requirements that represent the characteristics of a "monitor," delivering an electrical stimulus, followed by analyzing and interpreting the muscle's response to that stimulus (Naguib et al., 2018). Objective monitors provide a means for clinicians to assess the depth of the block in real-time, assisting in the redosing for maintenance of paralysis and the dosing for reversal drugs. Preventing RNMB requires that the patient receives accurate dosing of reversal drugs followed by safe extubation (removal of the artificial airway), and objective monitoring has been shown to accomplish this endpoint.

Mechanomyography. Mechanomyography (MMG) measures the force of contraction at the adductor pollicis muscle following ulnar nerve stimulation at the wrist. The contraction force is converted to an electrical signal displayed as an amplitude height on the monitor (Van Santen et al., 1999). MMG results are accurate, repeatable, and reproducible (Brull & Kopman, 2017). However, to ensure accurate measurements, a constant preload (resting tension) of 200-300g must be applied to the thumb when at rest (Viby-Mogensen & Claudius, 2015). MMG use is confined to the research setting due to the cumbersome setup and time requirement (McGrath, 2006; Hund et al., 2016). Another reason for the lack of applicability to the clinical setting is that the hand must be fixed with a brace to ensure immobility, and the thumb must move along the length of the recording transducer (Hund et al., 2016; McGrath, 2006). Consequently, MMG is the gold standard for measuring a TOFR and is the technology whereby all other neuromuscular monitors are compared but has no clinical applicability (Naguib et al., 2018).

Electromyography. Electromyography (EMG) measures the compound action potential (electrical signal) that occurs before muscle contraction through sensing electrodes on the skin of the muscle (Hund et al., 2016). EMG estimates the force of the contraction based on the strength of the electrical signal, similar to an electrocardiogram (ECG) of the heart. Given that it measures the electrical signal and not the direct muscle contraction, EMG can be placed on muscles anywhere in the body approved to be used for neuromuscular blockade management

(Brull & Kopman, 2017). Unlike MMG, EMG does not require a preload and is less affected by hypothermia (Naguib et al., 2018).

Additionally, EMG does not require immobility of the hand or wrist to ensure accuracy. Yet, if the hand or wrist need to be immobilized or is not available for monitoring, the accuracy of EMG is not affected (Brull & Kopman, 2017). EMG is interchangeable with MMG, making it the gold standard in clinical practice (Brull & Kopman, 2017). Consequently, EMG has been empirically shown to reduce RNMB after the administration of NMBA's and before removing the artificial airway due to the accurate display of the TOFR (Dahaba et al., 2002; Naguib et al., 2018).

Disadvantages. To date, there is only one commercially available EMG monitor (GE Electrosensor NMT), and it is integrated into the anesthesia monitor. Therefore, there are no portable, battery-operated EMG devices available commercially, but the Tetragraph (portable EMG) monitor is currently being trialed (Naguib et al., 2018). The size of the muscle being measured affects the strength of the EMG signal, as smaller muscles will provide less accuracy (Hund et al., 2016). EMG is not affected by the movement of the hand or wrist during measurement; however, it is affected by electrical interference like electrocautery (electrical surgical knife), noise from nearby electrical equipment, and radiofrequency from x-ray machines (Brull & Kopman, 2017; Hund et al., 2016). EMG requires the placement of five electrodes, and improper placement may result in the inability to detect the action potential (electrical) signal (Brull & Kopman, 2017).

Acceleromyography. AMG is the most widely used and available quantitative (objective) neuromuscular monitor in clinical practice (Brull & Kopman, 2017). AMG devices are small, portable, and designed for use in the operating room. Developed in the 1980s as a convenient and more accurate method of measuring neuromuscular blockade, AMG uses the same principle as MMG, but rather than measure the force of contraction, AMG measures the acceleration of the contraction in the thumb (Hund et al., 2016; Naguib et al., 2018). Since AMG measures isotonic muscle contraction, a preload is not required to ensure accuracy like MMG. AMG has demonstrated superiority in reducing RNMB compared to subjective measurements such as the PNS (Murphy et al., 2008). The TOF-Watch SX (AMG) has been the most widely used AMG monitor in research and practice and has demonstrated superiority over bedside tests, PNS, and anesthesia experience in identifying a TOFR < 0.9 (RNMB) (Bhananker et al., 2015).

Disadvantages. AMG and kinemyography (KMG) both overestimate the TOFR when compared to the "gold standard" technologies of MMG and EMG, with AMG overestimating the TOFR by as much as 0.1-0.5 (Brull & Kopman, 2017; Capron et al., 2004; Liang et al., 2013). However, when Piccioni et al. (2014) utilized the TOF-Watch SX during major abdominal surgeries, a TOFR of 1.0 with the TOF-Watch SX eliminated respiratory weakness following extubation. The TOF-Watch SX is a one-dimensional device and requires careful calibration and normalization to ensure accuracy and may account for the variations in accuracy versus the newer three-dimensional AMG devices, which do not (Nemes & Renew, 2020; Brull & Kopman, 2017).

The adductor pollicis muscle should be used to assess recovery from paralysis using an objective monitor whenever NMBAs are given. To date, most literature suggests that if using an AMG monitor, the TOFR should be returned to 1.0 (100% of return to baseline) to account for the overestimation to achieve adequate recovery (Naguib et al., 2018; Piccioni et al., 2014). AMG monitors display a value greater than 1.0 (100% of return to baseline), which has discouraged clinicians from their use (Nemes & Renew, 2020). This occurrence is known as the "staircase phenomenon" and is specific to the AMG device's measurement at the adductor pollicis muscle of the thumb (Hund et al., 2016). The facial muscles are not susceptible to the "staircase phenomenon" but should not be used to assess recovery from paralysis (Hund et al., 2016). Patients who have not received NMBAs should have a TOFR 1.0 (100% at baseline); however, in AMG devices, a TOFR > 1.0 is possible due to the increase in the strength of the signal from repeated nerve stimulation (Hund et al., 2016).

The manufacturers of these devices and the literature recommend using the initial value if it is > 1.0 (> 100%) as the patient's baseline TOFR (normalization). For example, if the AMG device reads a TOFR 1.2, this should be used as the baseline, and 90% of 1.2 or 120% would give a TOFR ~ 0.9. The second recommendation would be to perform a calibration by performing repeated measurements to assess the average TOFR as the patient's baseline (Naguib et al., 2018). The various AMG monitors' costs range from $800-$2400, which also helps explain anesthesia departments reserve in acquiring these devices (Brull & Kopman, 2017).

Kinemyography. Kinemyography (KMG) is the technology of the GE M-NMT Mechanosensor device stored at Marion General Hospital (MGH) in Marion, Indiana, in most of their operating rooms. KMG, similar to MMG and AMG, measures the force of muscle contraction but uses a piezoelectric strip attached to the thumb and index finger to measure that force. A sensor in the piezoelectric strip measures the degree of bending of the strip and converts the strength of the bending into an electrical signal (Brull & Kopman, 2017). Currently, GE's MNMT Mechanosensor (KMG) device is the only commercially available KMG device. The trend is to develop an ideal neuromuscular monitor using EMG technology because the thumb does not have to be immobile (Brull & Kopman, 2017; Salminen et al., 2016). The GE M-NMT

Mechanosensor provides repeatable and accurate results when compared to AMG technology, but also requires that a TOFR of 1.0 (100% of return to baseline) be obtained to reduced RNMB rather than a TOFR of 0.9 as with EMG (Ezer et al., 2014; Naguib et al., 2018; Salminen et al., 2016; Stewart et al., 2014).

Disadvantages. KMG technology, much like AMG technology, overestimates the TOFR by 0.1-0.25 compared to MMG and EMG and therefore cannot be used interchangeably unless the TOFR of 1.0 is achieved (Naguib et al., 2018; Salminen et al., 2016; Stewart et al., 2014). Like AMG, the thumb must be free to move throughout the surgery to prevent inaccurate results. KMG is also prone to the "staircase phenomenon" when measuring the adductor pollicis muscle and may therefore require that a TOFR > 1.0 (100%) be the baseline reading when assessing for recovery (Salminen et al., 2016; Stewart et al., 2014). Nevertheless, the GE M-NMT Mechanosensor has been shown to reduce the incidence of RNMB and the respiratory complications that follow (Ezer et al., 2014; Naguib et al., 2018; Salminen et al., 2016).

Summary of Supportive Evidence

The traditional and current practice of neuromuscular blockade management, which includes subjective tests, peripheral nerve stimulators, and neostigmine, has not reduced the incidence of RNMB and its consequences. RNMB places patients at significantly higher risk for CREs and POPCs, and even death, especially for patients who have weakened respiratory and neuromuscular physiology at baseline. The elderly (> 65 years of age) and obese (BMI > 30) are particularly at significant risk of CREs, POPCs, and death after receiving NMBAs during surgery. The literature has demonstrated that the best practice is to abandon subjective bedside tests. PNS should not be considered monitors and should be replaced with objective monitors that meet the requirements of what constitutes a "monitor." Without using an objective monitor, the clinician becomes the monitor, and research has demonstrated that the human eye and touch cannot discern RNMB when the TOFR is 0.5-0.9. Consequently, objective monitoring gives the clinician the best available tool to reduce the patient's risk of RNMB.

Neostigmine has been the primary drug for the reversal of NMBA-induced paralysis for over 50 years. However, neostigmine and AchE Inhibitors are imperfect reversal agents due to their indirect mechanism of action, but for years were the best option available to clinicians. In 2015, sugammadex was approved for use in the United States for the reversal of aminosteroidal NMBAs and has shown the ability to reduce RNMB and its consequences. However, the dosing of sugammadex still requires neuromuscular monitoring, as sugammadex without monitoring did not significantly reduce RNMB. The incidence of RNMB can be reduced using either drug if objective monitoring is used as part of neuromuscular blockade management.

AMG devices were first made commercially available in the 1980s to improve neuromuscular blockade management and reduce RNMB. To date, literature has shown the superiority of objective monitoring over subjective tests and PNSs to reduce RNMB, regardless of the type of objective monitor used. While the available objective monitors have been shown to reduce RNMB, the search for the ideal neuromuscular monitor continues to date. The PNS gained widespread use and popularity in anesthesia due to its ease of use, size, and portability. Many researchers believe the same will happen when an objective monitor that is small, portable, and reliable regardless of thumb mobility is produced.

Change to popular practices that are no longer best practices takes years to move away from, and the implementation of objective monitoring is no different. Surveys have shown that anesthesia clinicians are not aware of the incidence of RNMB and perceive objective monitoring devices to be inaccurate and cumbersome when encountered. The consensus statement put out by the leading researchers on neuromuscular blockade management acknowledges that education must be undertaken to bring awareness to the pervasiveness of RNMB and its consequences. Despite some of the shortcomings of objective monitors, it is the best tool available to reduce RNMB.

Marion General Hospital has an opportunity to adopt best practices of neuromuscular blockade management and keep patients as safe as possible from experiencing RNMB and its consequences. As the IARS has mentioned in their statement, clinicians need to be educated on the pervasiveness of RNMB as organizations attempt to adopt objective monitoring. However, Marion General Hospital has already decided some time ago to purchase objective monitors with their anesthesia machines; therefore, an educational initiative may help increase clinicians' understanding of the GE M-NMT Mechanosensor.

Chapter 3: Project Design

Methodology

Project Design

“Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors Amongst Anesthesia Providers” project was a quality improvement project and was conducted using a demographic survey and pre-test survey (Appendix B) via a provided QR code, followed by an educational PowerPoint presentation, and subsequently followed by the post-test survey (Appendix C) via a provided QR code. The project material, including an informed consent and disclosure form were handed out in a packet prior to the educational presentation. A demonstration on the proper use of the objective monitor occurred inside the operating room during surgeries with individual anesthesia providers. Subsequently, a two week trialing period of the objective neuromuscular monitor was planned to occur, followed by a survey which evaluated the anesthesia providers understanding and utilization of the monitor after trialing. However, anesthesia staffing inconsistencies at MGH required that the two-week trialing period be eliminated and the implementation modified. The pre and post-test surveys were identical to each other in questions.

The educational presentation did include the most recent literature on the incidence of RNMB, the consequences of RNMB, current practice standards, monitoring technologies, current practice patterns, and the benefits of objective monitoring. The entire presentation length was approximately ten slides, and the hands-on demonstration of the monitor did occur afterward. This DNP project compared current knowledge and attitudes, awareness of techniques, and practice patterns regarding neuromuscular monitoring in the intraoperative period before and after receiving an educational presentation and training on the use of objective neuromuscular monitors.

Ethical Considerations

The project manager had completed the Collaborative Institutional Training Initiative (CITI) program (April 2021) prior to project development (Appendix D). Participation in the DNP project was voluntary, anonymous, and informed consent (Appendix E) was obtained on the day of the educational intervention, prior to the demographic survey and pretest. All data remained protected by encryption via Microsoft Forms© with password protection to protect participant confidentiality and prevent unauthorized user access. There were no immediate or long-term risks for the participants as it pertains to the educational intervention. There was no monetary compensation for the participant’s participation other than a catered lunch after the implementation phase was completed. During the implementation of the project, no intentional deception or experimental procedures undertaken.

The project manager followed the guidelines provided by Microsoft Forms in order to ensure confidentiality and anonymity. The participants were given an anonymous identification number as a method to ensure confidentiality and only the project manager had access to the data.

Project Schedule

Table 1. demonstrates the project's timeline from conception to the dissemination of the project's findings. The timeline was also created to help the project manager stay on task for a timely implementation.

Implementation Methods

The educational intervention (Appendix H) was a PowerPoint presentation consisting of approximately ten slides requiring a duration of 10-15 minutes to read. However, the presentation did include the most recent literature on the incidence of RNMB, the consequences of RNMB, current practice standards, monitoring technologies, current practice patterns, and the benefits of objective monitoring. Following the presentation and post-test survey, a hands-on demonstration of the proper use of the objective neuromuscular monitors took place in the operating room during surgery with individual anesthesia providers.

Measures/Tools/Instruments

"Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors" project assessed awareness of the incidence and impact of residual neuromuscular blockade amongst anesthesia providers at Marion General Hospital both before and after receiving an educational presentation. The project aimed to compare current knowledge and attitudes regarding neuromuscular blockade management and assess practice patterns regarding neuromuscular monitoring in the intraoperative period before and after receiving an educational presentation and training on objective neuromuscular monitors.

Aim #1

Aim #1 is to increase anesthesia providers' awareness and perceptions of the incidence and consequences of residual neuromuscular blockade (RNMB) in current practice.

Outcome 1a

Following the educational intervention, the intended outcome following the intervention is for anesthesia providers to self-report an increased awareness of the conditions leading to the incidences and consequences of RNMB by a 30% increase over the total pretest scores.

Outcome 1b

Following the educational intervention, the intended outcome was that anesthesia providers will self-report that the best method to prevent residual neuromuscular blockade is by the use of objective neuromuscular monitors by a 20% increase over the total pretest scores.

Aim #2

Aim #2 is to increase anesthesia providers perceptions, knowledge, and understanding of objective neuromuscular monitors.

Outcome 1a

Following the educational intervention, the intended outcome is for anesthesia providers to self-report an increased understanding of objective neuromuscular monitors by a 20% increase over the total pretest scores.

Aim #3

Aim #3 is to improve the likelihood of anesthesia providers utilization of the objective neuromuscular monitors, and to decrease the risk and opportunities of residual neuromuscular blockade.

Outcome 1a

The intended outcome is to have knowledge and attitudes regarding objective neuromuscular monitoring postintervention and after hands-on demonstration to have increased from total preintervention scores.

Outcome 1b

Outcome 1b is to assess the likelihood of anesthesia providers utilizing objective neuromuscular monitoring in their future practice following this project's educational intervention and two week trialing of the objective neuromuscular monitors.

Evaluation Plan

The project manager was responsible for collecting the data and logging the data using a data collection flow chart. The project manager was also responsible for making sure that the data was complete. If the data of any participant was not complete, the completed data was utilized if possible and the presence of missing data was disclosed upon dissemination. Once the data was within Microsoft Forms, the project manager retrieved the data and used Microsoft Forms and Excel to calculate the gain scores (percentage change). The project manager was also responsible for cleaning the data and discarding the data in September 2022, once analysis and dissemination had been completed. The project manager utilized software designed to permanently erase electronic data and used a shredder for the destruction of paper formatted informed consents.

Methods for Collection of Data

The demographic survey (Appendix B) via Microsoft Forms© was utilized to assess the years of anesthesia practice, role in anesthesia (Anesthesiologist, CRNA, or SRNA), and age range. The demographic survey was used to assess how these variables impacted perceptions, attitudes, and willingness to change practice. The aim of the pretest (Appendix B) via Microsoft Forms© was to assess provider awareness and knowledge of the incidence of residual neuromuscular blockade and its consequences. Moreover, providers current methods of neuromuscular monitoring and management was also assessed utilizing the pretest questionnaire. In addition, the providers knowledge of evidence-based practices to reduce residual neuromuscular blockade was also assessed utilizing the pretest questionnaire. The post-test (Appendix C) constructed via Microsoft Forms© was utilized to assess the effectiveness of the educational intervention by comparing its scores to the pretest. The Understanding Objective Neuromuscular Monitors Survey Tool (Appendix G) constructed via Microsoft Forms© was utilized to assess the providers understanding, comfortability, barriers to use, and likelihood of future use. The data collection flow chart will help the project manager accurately translate the data. The participant responses of the demographic, pretest, and post-test, and was transferred from Microsoft Forms© to an Excel data sheet by the project manager. The Understanding Objective Neuromuscular Monitors Survey Tool (Appendix G) was never used due to the elimination of the two-week trialing period.

Data Analysis Plan

Given the small convenience sample size of nine participants, a gain score also known as “change scores” or “percentage change” was utilized to detect a change. Gain scores or “percentage change” cannot detect a statistically significant difference, but can detect a clinically significant difference. The gain scores will be used to measure a participants individual scores (difference between pretest and posttest) and the group's score, also known as the "average gain score," which measures the group's average pretest versus posttest scores. The gain score increase or decrease was calculated into percentages in order to evaluate if the outcomes of each aim has been achieved. The analysis of the Understanding Objective Neuromuscular Monitors Survey Tool (Appendix G) measures the confidence and understanding of the objective neuromuscular monitor amongst anesthesia providers, in this case, the GE Datex-Ohmeda M-NMT monitor.

Dissemination Plan

The executive summary was scheduled for completion by May 2022, with the dissemination of the results occurring in June 2022. The project manager disseminated the results of the project using a PowerPoint presentation to the University of Saint Francis faculty and DNP advisors. An abstract of the project's results was disseminated to the other stakeholders upon request. The Project Timeline (Table 1) summarizes the project activities and planned dates for the project.

Chapter 4: Results and Outcomes Analysis

Data Collection Techniques

The project manager was responsible for collecting the Microsoft Forms© data from February 1 to March 3, 2022. Once the data was within Microsoft Forms©, the project manager retrieved it and entered it into an excel data collection flow chart to organize the data and calculate the gain scores. A total of nine anesthesia providers (8 CRNAs and 1 SRNA) participated in the implementation of the quality improvement project. The project manager was also responsible for ensuring that the data was complete. As a result, all participants data was complete.

Measures/Indicators

"Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors…" project assessed the awareness of the incidence and impact of residual neuromuscular blockade amongst anesthesia providers at Marion General Hospital both before and after receiving an educational presentation. The project aimed to compare current knowledge and attitudes regarding neuromuscular blockade management and assess practice patterns regarding neuromuscular monitoring in the intraoperative period before and after receiving an educational presentation and training on objective neuromuscular monitors.

Aim #1

Aim #1 was to increase anesthesia providers' awareness and perceptions of residual neuromuscular blockade's (RNMB) incidence and consequences in current practice.

Outcome 1a

Following the educational intervention, the intended outcome was for anesthesia providers to self-report an increased awareness of the conditions leading to the incidences and consequences of RNMB by a 30% increase over the total pretest scores. In question #1, participants were asked if RNMB represented a significant problem in assessing awareness and perceptions. The pretest scores demonstrated that 33% strongly agreed and 56% agreed, but following the intervention, 67% strongly agreed and 22% agreed. Consequently, there was a 34% increase in the pretest to post-test intervention scores in the strongly agreed responses achieving the stated outcome of a 30% increase from pretest to post-test intervention (Figure 1).

Two questions were asked to assess participants' awareness of the conditions that lead to RNMB. Question #3 asked participants, "What site do you feel is best to monitor peripheral nerve response for recovery from neuromuscular blockade?" The pretest scores were 67% for the facial nerve and 33% for the ulnar nerve, while the post-test intervention scores were 44% for the facial nerve and 56% for the ulnar nerve. Consequently, an increase of 22% from the pretest to post-test intervention identified the most appropriate peripheral nerve to assess upon neuromuscular blockade recovery. 22% was an improvement but was short of the stated outcome goal of a 30% increase in the awareness of the conditions that led to RNMB following the intervention.

The most appropriate practice for assessing adequate paralysis for tracheal intubation and facilitation of surgery is assessing the facial nerve. However, using the facial nerve to assess for recovery from paralysis will overestimate the degree of neuromuscular function return. Consequently, The pre-test response of question #3 (Figure 2) demonstrates the knowledge deficit and practice patterns of anesthesia providers that lead to RNMB incidence and its consequences.

Question #7 asked participants, "Do you think that clinical signs (such as the ability to sustain a 5-second head lift and 5-second hand squeeze) are reliable indicators of the adequacy of neuromuscular recovery?' In the pretest scores, 56% said "yes," and 44% said "no." While the post-test intervention scores were 44% said "yes," and 56% said "no." Following the intervention, only a 12% increase was noted to have identified clinical bedside tests and signs as inadequate to monitor neuromuscular recovery to prevent RNMB. Consequently, the stated outcome goal of a 30% increase in awareness of the conditions that lead to RNMB was not obtained in the post-test intervention.

Outcome 1b

Following the educational intervention, the intended outcome was that anesthesia providers will self-report that the best method to prevent residual neuromuscular blockade is by the use of objective neuromuscular monitors by a 20% increase over the total pretest scores. Question #9 asked the participants, "if the routine use of objective neuromuscular monitors would not reduce the incidence of RNMB?" The pretest scores demonstrated that 22% strongly disagreed and 56% disagreed, while post-test scores demonstrated that 33% strongly disagreed and 33% disagreed following the intervention. The pretest score summation of the strongly disagree and disagree was 78%, and the post-test score summation of the strongly disagree and disagree 67%. Consequently, there was an 11% decrease following the intervention in participants' belief that objective neuromuscular monitors would reduce RNMB. However, the pre and post-test scoring could have been affected by the question's wording producing confusion for the participant.

Aim #2

Aim #2 was to increase anesthesia providers' perceptions, knowledge, and understanding of objective neuromuscular monitors.

Outcome 1a

Following the educational intervention, the intended outcome is for anesthesia providers to self-report an increased understanding of objective neuromuscular monitors by a 20% increase over the total pretest scores. Two questions were asked to assess participants' knowledge and understanding of objective neuromuscular monitors. Question #4 asked participants, "What is the most reliable method for determining if you need to administer or omit neuromuscular reversal agents?" The pretest scores of participants were physical criteria (67%), TOF count (22%), and TOF ratio (11%). Following the intervention, the post-test scores were physical criteria (33%), TOF count (0%), and TOF ratio (67%). Consequently, there was a 56% increase in participants' knowledge and understanding of objective neuromuscular monitors compared to preintervention. The stated outcome goal of a 20% increase in knowledge and understanding of objective neuromuscular monitors was achieved.

The pre-test response to question #4 (Figure 3) demonstrates the gap in evidence-based practice and the current practice of anesthesia providers when it comes to preventing RNMB incidence and its consequences. Most participants stated pre-intervention that they rely on clinical signs to assess neuromuscular function's adequate return, which is the least sensitive out of the three measurements.

Question #8 asked participants, "Prior to tracheal extubation, the TOF ratio should be?" The pretest scores were TOF ratio 91-100% (67%), TOF ratio 81-90% (22%), and TOF ratio 71-80% (11%). Following the intervention, the post-test scores were TOF ratio 91-100% (89%), TOF ratio 81-90% (11%), and TOF ratio 71-80% (0%). Consequently, there was a 22% increase in the knowledge and understanding of objective neuromuscular monitors, and the stated outcome goal of a 20% increase was achieved.

Aim #3

Aim #3 was to improve the likelihood of anesthesia providers' utilization of the objective neuromuscular monitors and decrease the risk and opportunities of residual neuromuscular blockade.

Outcome 1a

The intended outcome was to have knowledge and attitudes regarding objective neuromuscular monitoring postintervention and, after a hands-on demonstration, increase from total preintervention scores. To assess a change in practice and attitudes, question #2 asked participants, "How often will you monitor neuromuscular function in your patients receiving muscle relaxants?" The pretest scores responses were always (56%), often (22%), rarely (11%), and never (11%). Post-intervention (Figure 4) and following a hands-on demonstration, the scores were always (67%), often (22%), rarely (0%), and never (11%). There was an 11% (one participant) increase in knowledge and attitudes towards always utilizing neuromuscular monitoring when assessing for neuromuscular recovery.

All but one participant was willing to change their practice. However, one of the expected outcomes of this quality improvement project was the use of the objective monitor by one anesthesia provider during their practice. One anesthesia provider administers thousands of anesthetics a year where NMBAs are used and can substantially impact the prevention and reduction of RNMB.

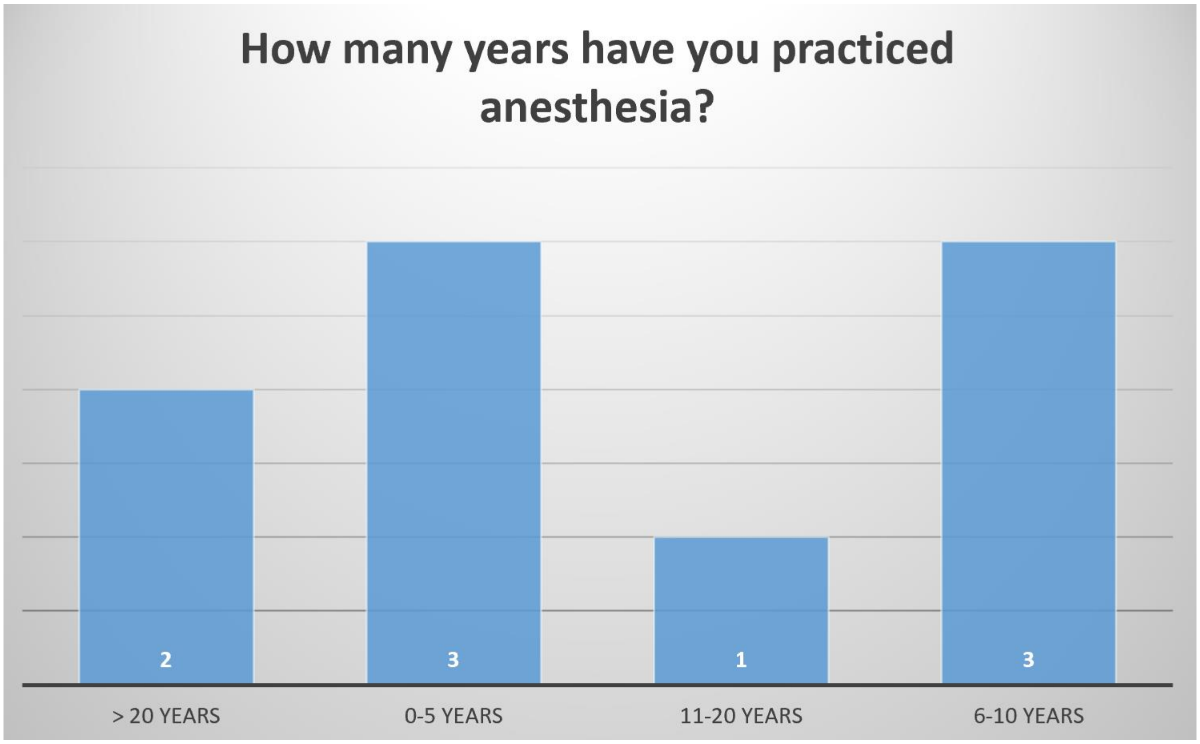
Outcome 1b

Outcome 1b was to assess the likelihood of anesthesia providers utilizing objective neuromuscular monitoring in their future practice following this project's educational intervention and hands-on demonstration of the objective neuromuscular monitors. Question #11 asked participants, "How likely are you to change your practice habits in the future?" The pretest responses were very likely (22%), somewhat likely (11%), neither (33%), somewhat unlikely (0%), and very unlikely (33%). Following the intervention and hands-on demonstration, the responses (Figure 5) were very likely (22%), somewhat likely (44%), neither (11%), somewhat unlikely (0%), and very unlikely (22%). There was a 44% (three participants) increase in the "somewhat likely" to change neuromuscular management practice habits category following the intervention and hands-on demonstration.

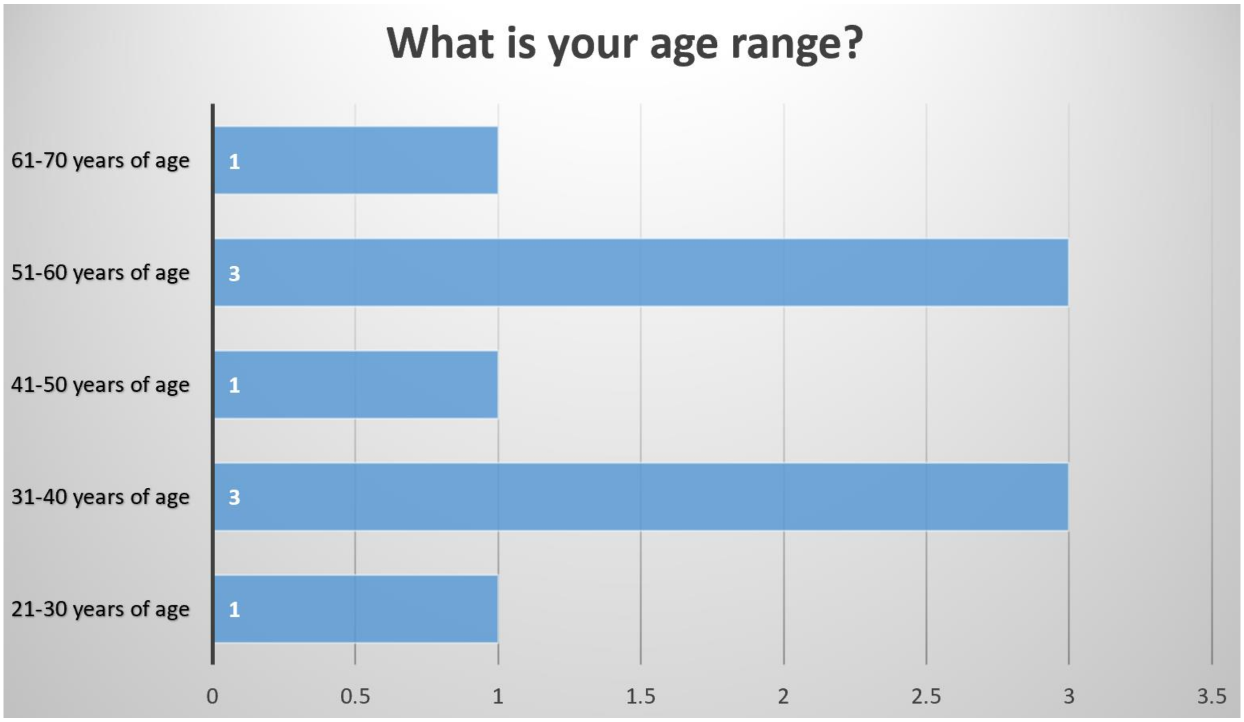
Although only one participant from question #2 was willing to change from rarely monitoring patients' neuromuscular recovery to always, most anesthesia providers were willing to change some aspects of their practice to prevent and reduce RNMB. The change in practice may not be by monitoring; it may be using the ulnar nerve instead of the facial nerve or always administering paralysis reversal drugs.

Data Analysis Inferences

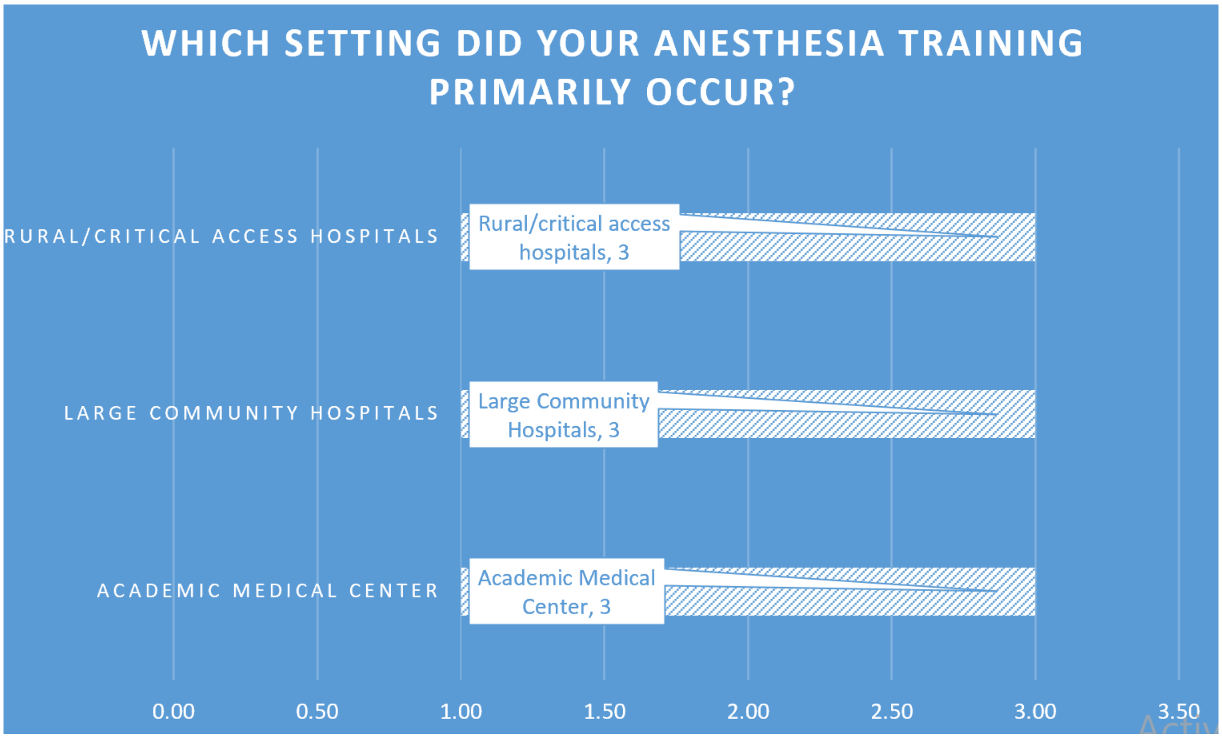
The demographic survey demonstrated an equal split in experience between the 0-5 years of experience (33%) and 6-10 years of experience (33%), with (33%) having > 11 years of experience (Figure 6). All participants were CRNAs except for one SRNA.



In question #2 (Figure 7) of the demographic survey, most participants were either 31-40 years of age (33%) or 51-60 years of age (33%).



The practice setting (Figure 8) where the anesthesia providers trained was diverse and equally distributive with the academic setting (33%), the large community hospital (33%), and the rural/critical care access (33%). Therefore, inferences cannot be made about the impact of anesthesia training on the management of neuromuscular blockade.



Awareness of RNMB as a significant clinical problem was high amongst participants both pre-intervention (89%) and post-intervention (89%) when the agreed and strongly agreed were totaled. When compared to the most recent survey in the United States on the significance of RNMB amongst anesthesiologists (Naguib et al., 2010), 64% of respondents estimated the clinical significance of RNMB as less than 1%. Consequently, both pre and post-intervention, anesthesia providers overwhelmingly perceived RNMB as a clinically significant problem.

When discussing how to reduce the incidence and consequences of RNMB, questions were asked to assess the knowledge and current practice patterns of anesthesia providers' management of neuromuscular blockade. Only two-thirds (67%) of anesthesia providers "always" monitor neuromuscular function using subjective or objective monitoring. The remaining 33% stated intent to continue to use time since the last administration and clinical tests (5-second head lift, etc.). Using the ulnar nerve of the thumb is the evidence-based best practice to assess neuromuscular recovery. Even post-intervention, only 56% of anesthesia providers felt the ulnar nerve was the best site to assess neuromuscular recovery. The decision not to use any monitor (clinical bedside tests, time, etc.) or to use a subjective monitor at the facial nerve rather than the ulnar nerve will lead to an increased incidence of RNMB.

Besides always using a monitor, preferably an objective monitor if available. There are a few evidence-based practices in neuromuscular blockade management that will reduce the incidence of RNMB. First, always administer a reversal agent if a non-depolarizing muscle relaxant was given. In both the pre and post-intervention scores, 89% of anesthesia providers always used a reversal agent when a non-depolarizing muscle relaxant was given. Two, regardless of which monitor is available, always use the ulnar nerve to assess for neuromuscular recovery. Post-intervention, 56% of anesthesia providers felt the facial nerve to be the most reliable nerve to evaluate recovery from paralysis. Lastly, always use a subjective monitor if no objective monitor is available. Time since last administration and clinical bedside tests are grossly unreliable when assessing for recovery from paralysis. Post-intervention, 49% of anesthesia providers believed clinical bedside tests to be reliable indicators of recovery from paralysis.

Gaps

No gaps were identified in the data. All nine of the participants completed the surveys.

Unanticipated Consequences

During the time of implementation, unanticipated consequences in data collection did occur as MGH utilized contracted anesthesia staffing while building up their permanent staff. Under these circumstances, the planned two-week trialing period was eliminated, and the hands-on demonstration was modified. The contracted anesthesia staff's presence was irregular and made conducting the two-week trialing period impossible. The frequent change over in staffing also made it impossible to provide the educational intervention in one to two settings. Therefore, the educational intervention was presented one-on-one to the anesthesia providers. Also, the project manager carried the objective neuromuscular monitor from surgery to surgery to provide a hands-on demonstration to the anesthesia provider performing anesthesia with the project manager at that time. However, the overall aims and goals of implementation were achieved.

Expenditures

The overall expenditures were $92 on laminated reminders at every anesthesia machine during the two-week trialing period. However, the two-week trialing period had to be eliminated due to the irregular presence of contracted staffing. At the end of the project manager's rotation on March 4, 2022, lunch was catered for the entire staff, courtesy of the project manager, to ensure that all who helped facilitate the implementation of this project were included. The total cost of catered lunch was $400. The price of material for the presentation and a locked box for informed consent was $76. The total expenditure was $568.

Chapter 5: Leadership and Management

Organizational Culture

The facility the project manager chose to implement the DNP Project was Marion General Hospital (MGH) in Marion, Indiana. MGH is a 99-bed, non-profit, rural community hospital founded in 1896 by Dr. T.C. Kimball (physician) and J.M. Barnard (insurance agent) as Grant County Hospital (Aaron, 2001). Since 1896, when the first Marion General Hospital was a house, MGH has continued to evolve and expand to meet the needs of Grant County. As a non-profit organization, MGH is not beholden to shareholders' demands but the community's demands. MGH has a clear mission, to transform the health of the community through patient-centered, high quality, and affordable care (MGH, 2021). Employees appear to understand and endorse the mission given the feedback provided via interviews.

The employees are dedicated to providing quality care and speaking up as patient advocates. Recently, there has been significant turnover in perioperative nurses, certified surgical technicians (CST), and Certified Registered Nurse Anesthetists (CRNA) due to newly hired surgeons working late and utilizing the on-call staff routinely. Consequently, this has created a pessimistic culture in the perioperative areas. However, MGH surgical management has shown flexibility and a willingness to adapt by hiring a night shift RN and CST to mitigate any potential attrition of RNs and CSTs.

Open Systems Model

The project manager chose to utilize the Open Systems Model (Appendix K) in the assessment of MGH, which is the site of implementation for the project manager’s DNP project. The Open Systems Model best describes the desired and undesired behavior of an organization.

Like living organisms seeking to survive or thrive within their environment, organizations also seek to thrive given the environment (culture) within and without the organization. The value in utilizing an Open Systems Model is the ability to analyze and assess the organization's culture, providing a framework for improving processes and tackling specific issues and challenges to the organization (Breckenridge Institute, 2016).

Appendix K. demonstrates the key components to an open system, where inputs represent material resources and feedback from the environment, and processes are driven by the mission or goals of the organization, and outputs are the services or products exported to the external environment (customers, patients, etc.). The organization links its mission and goals to the needs of the external environment providing the organization with purpose. Consequently, the needs of the external environment are continually examined through strategic and tactical feedback. Tactical feedback is used to measure whether the organization is meeting its mission and goals. Strategic feedback is an evaluation of whether an organization meets the needs of the consumers of their products or services (Breckenridge Institute, 2016).

The Open System Model fits well with the project manager’s DNP project within the organizational culture of MGH as it allows for continual examination of the processes of implementation and the interactions of those processes within the implementation environment. Open systems also examine the organizational climate within the organizational boundaries as seen in the Appendix K. diagram. The Breckenridge Institute (2016) characterizes the organizational climate as the atmosphere that permeates the workplace. The atmosphere includes employee morale, staff's confidence in management, capacity for innovation, and a willingness to change. The organizational climate at MGH has demonstrated a capacity for innovation and change. However, the challenge for the project manager is the capacity of the anesthesia team to adopt a more effective method of neuromuscular monitoring. Consequently, an open systems view allows for adaptability based on the feedback from within and without the organizational boundary.

The literature demonstrates interventions to reduce or eliminate residual neuromuscular blockade (RNMB) have been met with resistance across the profession. Therefore, the project manager and DNP Advisor already accounted for alternative methods to increase the knowledge of RNMB and understanding and utilization of objective neuromuscular monitoring. Although MGH is an organization of innovation and change, the anesthesia group are contracted employees who may not see the significance of the implementation of the project.

Change Strategy

The barriers to implementation and use of quantitative (objective) monitors have been documented in the literature. Since the 1980s, objective monitors have been available for clinical practice (Viby-Mogensen et al., 1988). However, the use of bedside tests and peripheral nerve stimulator (subjective) monitors had already taken hold as the pillars of neuromuscular management in anesthesia (Nemes & Renew, 2020). Consequently, forty years after the first commercially available objective monitors, resistance to a change in practice has become the primary hurdle to the implementation of these monitors for a multitude of reasons (Naguib et al., 2018). Surveys and literature have documented the most widely stated barriers to objective neuromuscular monitor use, such as the additional time consumption, inconsistent readings, and lack of suitable alternatives when the thumb is not readily available. (Hund et al., 2016; Oh et al., 2020; Soderstrom et al., 2017).

One of the goals of “Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors Amongst Anesthesia Providers” project was aimed at addressing, informing, and reducing these barriers to objective neuromuscular monitors using Lewin’s Theory of Change. From personal interviews with the anesthesia providers at MGH, some of the barriers stated above were mentioned as personal barriers to objective neuromuscular monitor utilization. However, a lack of awareness of RNMB and the availability of objective neuromuscular monitoring were also mentioned. When examining "assessing barriers to knowledge use" and "selecting and tailoring implementation interventions" of the KTA Action Cycle, the utilization of Lewin's Theory of Change: Force Field Model helped move the project through these two critical phases.

To change social groups' behavior, Lewin hypothesized that group behavior was influenced by a dynamic balance of forces that constantly worked in opposition to each other. The driving forces for change must overcome the restraining forces for the status quo to progress through the three stages of change (unfreeze, change, and refreeze) (Burnes, 2004). The status quo is maintained by the restraining forces or group behavior, which also affects individual decisions and behaviors. Todd et al. (2014) found the utilization of objective monitoring reached nearly 100% when there was a strong departmental champion and mentor facilitating the implementation strategies towards this endpoint, but the effort took nearly two years.

The project manager’s goal was to strengthen the driving forces or diminish the restraining forces in order to facilitate a change in practice. However, the project manager was not able to convince the departmental head of the significance of the project. Unlike the Todd et al. (2014) findings, not having the departmental head become a champion for the change in practice did prompt the project manager to focus more on diminishing the restraining forces. The attempt at diminishing the restraining forces was done by the project manager carrying the objective neuromuscular monitor to every surgical case where neuromuscular relaxant drugs were to be used.

The change in strategy allowed the anesthesia providers in the operating room with the project manager to learn about the monitor and see it in use. Additionally, there were mostly contracted anesthesia providers filling in the openings at MGH for a week out of the month. This made it extremely difficult to implement a single presentation on the objective neuromuscular monitors and to implement the two-week trialing period following the interventional presentation. Consequently, each anesthesia provider was presented with the demographic survey, pretest, intervention, and post-test when time allowed for them to participate and as mentioned above, the monitor was carried with the project manager for quick introduction and demonstration.

Leadership Style

As mentioned before, the organization is led primarily by women (Stephanie Hilton-Siebert—President/CEO, Barbara Ihrke—Chair of Board of Directors, and Cindy Futrell—CNO) who are nurses by trade and from the community. The board of directors is primarily composed of physicians, but the atmosphere feels collegial and collaborative. Additionally, the Board of Directors physicians is equally women and men of various cultures and ethnicities, presenting a diverse leadership body. The Director of Surgical Services, Brandon Scott, and the Operating Room Manager, Tracy Livingston, have been with the organization for over 20 years and feel supported by the organization's leadership.

The project manager’s leadership style was mostly democratic, as soliciting group opinion for the solution to a problem is believed to work most effectively and offer more buy-in. However, in the absence of a problem requiring a solution, a pacesetting leadership style was generally the project manager’s leadership style. High standards, accountability, and ownership are important to achieving good outcomes. The chief certified registered nurse anesthetist (CRNA) leadership style tended to be a mix of pacesetting and coaching. The chief CRNA was easily approachable and took a vested interest in others' personal and professional development. However, he was open and honest about the lack of awareness of the availability of the objective neuromuscular monitors at MGH. Still, he thought that the use of the newest reversal drug (sugammadex) negated using anything other than a subjective monitor.

Given the chief CRNAs leadership style, the project manager was able to adapt the project to increase awareness of RNMB and provide awareness of the availability of the monitor while performing hands-on teaching in a different format than initially proposed. The cultural environment of the operating room and anesthesia staff was such that adaptation of the initial plan was possible and successful in some of the project’s aims and goals.

Interprofessional Collaboration

“Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors Amongst Anesthesia Providers” was a quality improvement (QI) project confined to the operating room and occasionally the recovery room. Doug Pruitt (Chief CRNA) and the clinical coordinator for MGH was supportive in offering as much time as required to facilitate the project’s implementation. The Director of Surgical Services, Brandon Scott RN, was very supportive when it came to innovative changes in the OR and implementation of EBP. Tracy

Livingston RN (OR Manager) expressed his support for the project and pledged staff support whenever possible, given the turnover in staffing. Dr. Keith Cotrell, DNAP CRNA (Project Advisor), mentored the project manager through the planning and implementation of the project. Dr. Cotrell was creative in assisting the project manager with adapting the project to the current environment, which was different from the environment during the planning phase.

Conflict Management

There were no surprises when it came to the implementation of the project. Dr. Cotrell and the project manager were aware of the profession's resistance to the use of objective neuromuscular monitors. After arriving at MGH, the project manager communicated with Doug Pruitt (Chief CRNA) and was informed that staffing was such that a single presentation would not be feasible short of getting two participants at a time. Therefore, the largest barrier to the project was the presence of contracted anesthesia providers who were at MGH for a day up to a week at a time. Consequently, the single presentation had to be modified to individual presentations, and the two-week trialing period was eliminated with a modified version of trialing the monitors.

Multiple anesthesia providers communicated a desire not to use the monitors when the project manager was not staffing the surgery. The desire not to use the monitors was not derived solely from inexperience with the monitor but a desire not to use the monitor for multiple reasons. The conflict was in finding the barriers present and demonstrating creativity to find other ways to increase awareness of residual neuromuscular blockade and increase knowledge and perception about objective neuromuscular monitors. Consequently, presenting the presentation to anesthesia providers on a one-on-one basis and carrying the objective neuromuscular monitor each day helped to accomplish the overall goal of the project and reduce conflict and misunderstandings.

Chapter 6: Discussion

Impact of Project

The aims of “Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors Amongst Anesthesia Providers” were to increase awareness, knowledge, and perceptions of the neuromuscular monitors amongst anesthesia providers at MGH. However, the overall aims and goals were to reduce the incidence of RNMB at MGH by bringing awareness to the availability of the GE M-NMT (KMG) monitors and closing existing knowledge gaps. However, not all permanent anesthesia staff were present at MGH at the time of implementation. Therefore, both the existing permanent staff and contracted staff were presented with the QI project and made aware of the availability and utility of the GE M-NMT (KMG) monitors, which have been proven to reduce the incidence of RNMB.

Most providers were happy to see the monitor in use. However, providers also verbally conveyed to the project manager that the likelihood of them using the monitor while at MGH was very unlikely. The openness about the unlikelihood of using the monitors would have precluded the implementation of the two-week trialing period even if all providers’ were the permanent staff. Nevertheless, the anesthesia providers present during the month of implementation are aware the monitor can be used as additional information when there is difficulty making a differential diagnosis when patients are slow to restore their breathing.

Decisions and Recommendations

The project manager's recommendations to anesthesia providers at MGH were to use the monitor if the provider's traditional practice cannot rule out residual paralysis at the end of surgery. In all likelihood, the above scenario may be the best hoped for as most anesthesia providers viewed the monitor as cumbersome despite the hands-on demonstration. In addition, time consumption, unfamiliarity with the monitor, and comfortability with their current practice all contributed to a lack of desire to utilize the monitor. Therefore, when reassessing the aims and objectives of "Increasing the Understanding and Utilization of Objective Neuromuscular Monitors Amongst Anesthesia Providers," Lewin's Theory of Change and Force Field Model is emphasized. Despite increasing awareness of the incidence and consequences of RNMB and basic knowledge of the objective neuromuscular monitors, the "driving forces" could not overcome the "restraining forces" to provide a cultural change in practice.

Limitations of the Project

The limitation of the QI project was the sample size of nine participants at a 99-bed community hospital, in which the findings from the project cannot be generalized. Additionally, statistical analysis could not be obtained in order to make generalizations due to the small sample size. The inconsistent staffing of the anesthesia department significantly contributed to the limitations of the project and was the most significant barrier. Contracted anesthesia providers' who were filling in had very little incentive to utilize the monitors specific to MGH.

Application to Other Settings

The application of the QI project is limited to the organizations whose operating rooms have quantitative (objective) monitors available. Out of the 20 clinical sites where the project manager was able to rotate through, only 2 out of the 20 had these monitors available to them. The literature states, as EMG technology becomes more portable and user-friendly, more anesthesia department heads will likely purchase these devices. Unfortunately, at this point in time, the currently available objective monitors have not been able to overcome the barriers that have existed for years in the literature. However, devices like Blink Company's TwitchView Train of Four Monitor may be able to overcome these barriers in the foreseeable future.

Strategies for Maintaining and Sustaining

EMG quantitative (objective) neuromuscular monitors are the future of objective monitors. Consequently, monitors like the GE M-NMT (KMG) at MGH are being stored in the bottom of drawers or placed in the anesthesia supply room. The strategies for sustainability are to continue raising awareness of the incidence and consequences of RNMB. One method to accomplish this sustainability is through routine competencies presented either by the anesthesia group or the organization annually or bi-annually. For example, Todd et al., (2014) obtained nearly 100% use of objective neuromuscular monitors at their hospital. But, the 100% usage was after two years of the anesthesia department head being a champion for this change.

However, the increased availability of the newest reversal drug Sugammadex will be a restraining force against the status quo in neuromuscular management. Anesthesia department heads have become champions for the availability of Sugammadex in the operating rooms, but not for objective neuromuscular monitors. When the pharmacy pushes back against the increased use of Sugammadex, anesthesia department heads champion the drug and also provide pushback. Unfortunately, this has not been the case for the acquisition of objective neuromuscular monitors and their use, and is unlikely to change anytime soon.

Lessons Learned

The lessons learned from "Increasing the Understanding and Utilization of Objective (Quantitative) Neuromuscular Monitors Amongst Anesthesia Providers" project were a single educational intervention may be adequate to institute change but inadequate to sustain the change. The project often has to live in the Action Cycle of Graham's KTA framework. Where barriers are encountered, and initiatives are created and implemented to overcome them, but if the intervention fails during "outcome evaluation." Project managers should not give up but return to the "select, tailor, implement interventions" stage of the Action Cycle until an intervention is created to overcome barriers to improvement and produce the intending outcome. Consequently, the lesson is that QI projects should be viewed as QI processes because they are a process of creation, adaptation, and evaluation that will have to be repeated many times.

DNP Essential I: Scientific Underpinnings for Practice was met by constructing the literature search for the QI project and synthesizing the literature. DNP Essential II: Organizational and System Leadership for Quality Improvement and Systems Thinking was met by conducting an assessment of the implementation site using the Open Systems Model Framework (Appendix K). Additionally, DNP Essential II was met by creating a comprehensive SWOT analysis. DNP Essential III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice was met by completing core training such as CITI Training to protect human subjects in research. DNP Essential III was also met by the construction and submission of an IRB proposal, followed by the implementation of the DNP project with findings disseminated to USF faculty.

DNP Essential IV: Information Systems/Technology and Patient Care Technology for Improvement and Transformation of Health Care was met by performing data extraction activities from large data sets provided by Parkview Regional Medical Center’s (PRMC) information systems staff. The project manager’s role was to help PRMC increase barcode scanning compliance by examining large data sets to determine which units and what drugs were not being scanned. DNP Essential V: Health Care Policy for Advocacy in Health Care was met by critiquing peers' policy brief. DNP Essential VI: Interprofessional Collaboration for Improving Patient and Population Health Outcomes was met by consulting with a subject matter expert Steven Byerly (GE Healthcare), by phone and email. DNP Essential VII: Advanced Nursing Practice was met by mentoring undergraduate nursing students aspiring to become nurse anesthetists.

Chapter 7: Conclusion

Potential Project Impact on Health Outcomes Beyond Implementation Site

The potential impact on health outcomes outside of the implementation site is limited as it pertains to quantitative (objective) neuromuscular monitoring. MGH was only one of two organizations out of approximately 20 clinical sites that had purchased the objective neuromuscular monitors. Therefore, the most significant barrier to reducing residual neuromuscular blockade (RNMB) is the absence of the monitors, which is the case at all but two of the clinical sites visited within the project manager's clinical rotations.

Health Policy Implications of Project

As capital budgets of organizations begin to become stretched due to the increased expense of staffing in the era of COVID-19, anesthesia groups negotiate to keep contracts and stay competitive. As a result, the desire to make additional device purchases for the anesthesia department becomes less and less of a reality. In addition, none of the quality indicators for reimbursement from the Centers for Medicare and Medicaid (CMS) and other health insurers specifically address residual neuromuscular blockade (RNMB). However, slower turnaround times in the operating room (OR) and critical respiratory events (CRE), and postoperative pulmonary complications (POPC) in the PACU affect the bottom line of organizations. Consequently, until organizations are able to see a loss of revenue directly attributable to RNMB, it is unlikely that current neuromuscular blockade reversal practices will change at the organizational level. Unfortunately, changes to practice often follow significant adverse events that may have occurred within the organization or made headline news because they occurred at some organizations across the country.

Proposed Future Direction for Practice

As more device manufacturers see the need, demand, and financial benefit of producing a quantitative (objective) neuromuscular monitor that is user-friendly, augments anesthesia practice, and addresses most of the shortcomings of the currently available monitors will begin to become readily available. One such monitor with promise is the TwitchView Train of Four Monitor made by Blink Device Company (see Appendix L). The platform of this monitor is similar to the build of an iPad or tablet, which enhances the device-to-user interface as touch screens are now an intuitive and preferable action to many when interacting with electronics.

The device uses the EMG technology, which is superior to KMG and AMG technology and resembles the accuracy of MMG, which is the gold standard of neuromuscular monitoring (Bowdle et al., 2020; Naguib et al., 2018). With the TwitchView Train of Four Monitor utilizing EMG technology, it does not matter if the thumb is tucked at the patient's side with the rest of their arm when the monitor checks for the train-of-four count and ratio as do the AMG and GE M-NMT (KMG) monitors. Additionally, the TwitchView monitor is portable and can be attached to an IV pole. The TwitchView monitor is the first portable neuromuscular monitor whose values can be integrated into the electronic medical record (EMR) via the anesthesia machine. TwitchView’s values will populate onto the anesthesia monitor in real-time, and the anesthesia monitor's values will show up in a patient's anesthesia record.

Time has shown that the current AMG and KMG neuromuscular monitors will not be adopted nationally despite the incidence and prevalence of RNMB unless the shortcomings of these monitors are addressed (Bowdle & Jelaic, 2020; Naguib et al., 2018). Therefore, the future of reducing RNMB in anesthesia practice will rely on the affordability and user-friendly EMG devices that require little to no calibration with simple electrode placement and quick monitoring.

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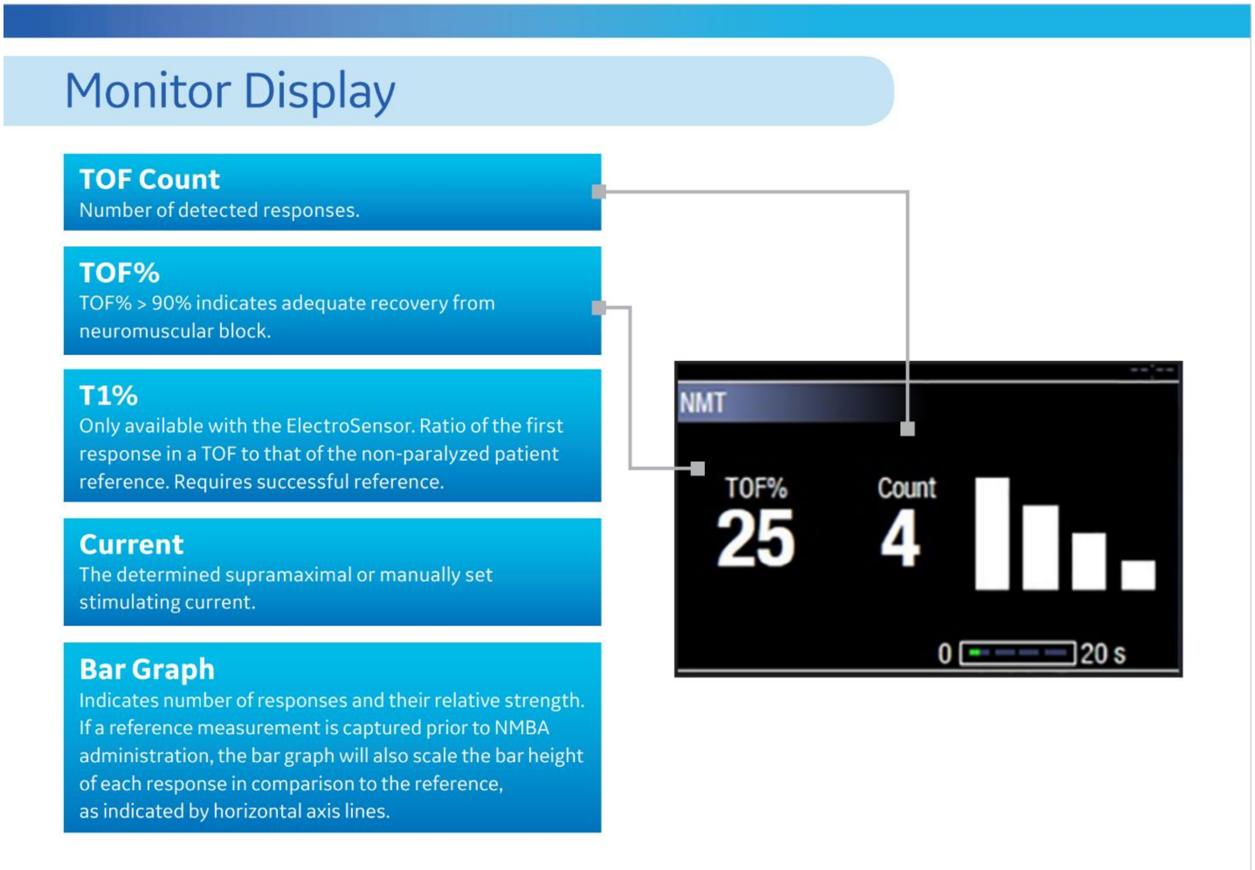
Appendices

Appendix A.

Visual Analog of Train-of-Four Count and Train-of-Four Ratio



Neuromuscular Transmission Module Pocket Guide, 2019; gehealthcare.com

Appendix B.

Demographic Survey

Please select only one answer from each question.

1.How many years have you practiced anesthesia?

- 0-5 years
- 6-10 years
- 11-20 years
- > 20 years

2.What is your role?

- Anesthesiologist physician
- CRNA
- SRNA

3.What is your age range?

- 21-30 years of age
- 31-40 years of age
- 41-50 years of age
- 51-60 years of age
- 61-70 years of age

Pretest

1. **Residual neuromuscular blockade represents a significant clinical problem (Please select only one answer).**

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

2. **How often will you monitor neuromuscular function in your patients receiving muscle relaxant?**
(Please select one answer).

- Never
- Rarely (once a month)
- Sometimes (2-3 times a month)
- Often (most cases)
- Always

3. **What site do you feel is BEST to monitor peripheral nerve response for recovery from neuromuscular blockade?**
(Please select only one answer).

- Facial nerve
- Ulnar nerve
- Neither

4. **The MOST reliable method for determining if you need to administer or omit reversal agents?**
(Please select only one answer).

- Train of Four twitch count
- Timing since last neuromuscular blocking drug
- Physical assessment criteria—Head lift, hand squeeze, tidal volume, and respiratory rate
- Train of Four ratio using an AMG, KMG, or EMG monitor

5. **When a nondepolarizing relaxant has been given, do you ALWAYS administer an anticholinesterase or sugammadex at the end of surgery?**

- ○ Yes
- ○ No

6. **If the answer above is No, which of the following factors helps in making that decision? Choose all that apply**.

- ☐ Total dose of non-depolarizing relaxant
- ☐ Timing of the last dose of non-depolarizing relaxant
- ☐ Absence of fade when using a conventional nerve stimulator
- ☐ Measurement of TOF ratio using a quantitative monitor
- ☐ No evidence of clinical weakness
- ☐ Using a specific non-depolarizing relaxant
- ☐ None of the above

7. **Do you think that the clinical signs (such as the ability to sustain a 5-s head lift) are reliable indicators of the adequacy of neuromuscular recovery?**

- ○ Yes
- ○ No

8. **Prior to tracheal extubation, the TOF ratio should be?**
   (Please select only one answer).

- ○ < 50%-60%
- ○ 61-70%
- ○ 71-80%
- ○ 81-90%
- ○ 91-100%

9. **Routine use of quantitative neuromuscular monitoring would NOT reduce the incidence of residual neuromuscular blockade.**
   (Please select one answer).

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly agree

10. **Tactile or visual assessment of TOF counts can reliably detect residual paralysis?**

- Yes
- No

11. **Following this intervention, how likely are you to change your practice habits in the future?**
(Please select only one answer).

- Very unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Very likely

Submit

Appendix C.

Posttest

1. **Residual neuromuscular blockade represents a significant clinical problem (Please select only one answer).**

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

2. **How often will you monitor neuromuscular function in your patients receiving muscle relaxant?**
(Please select one answer).

- Never
- Rarely (once a month)
- Sometimes (2-3 times a month)
- Often (most cases)
- Always

3. **What site do you feel is BEST to monitor peripheral nerve response for recovery from neuromuscular blockade?**
(Please select only one answer).

- Facial nerve
- Ulnar nerve
- Neither

4. **The MOST reliable method for determining if you need to administer or omit reversal agents?**
(Please select only one answer).

- Train of Four twitch count
- Timing since last neuromuscular blocking drug
- Physical assessment criteria—Head lift, hand squeeze, tidal volume, and respiratory rate
- Train of Four ratio using an AMG, KMG, or EMG monitor

5. **When a nondepolarizing relaxant has been given, do you ALWAYS administer an anticholinesterase or sugammadex at the end of surgery?**

- ○ Yes
- ○ No

6. **If the answer above is No, which of the following factors helps in making that decision? Choose all that apply**.

- ☐ Total dose of non-depolarizing relaxant
- ☐ Timing of the last dose of non-depolarizing relaxant
- ☐ Absence of fade when using a conventional nerve stimulator
- ☐ Measurement of TOF ratio using a quantitative monitor
- ☐ No evidence of clinical weakness
- ☐ Using a specific non-depolarizing relaxant
- ☐ None of the above

7. **Do you think that the clinical signs (such as the ability to sustain a 5-s head lift) are reliable indicators of the adequacy of neuromuscular recovery?**

- ○ Yes
- ○ No

8. **Prior to tracheal extubation, the TOF ratio should be?**
(Please select only one answer).

- ○ < 50%-60%
- ○ 61-70%
- ○ 71-80%
- ○ 81-90%
- ○ 91-100%

9. **Routine use of quantitative neuromuscular monitoring would NOT reduce the incidence of residual neuromuscular blockade.**
(Please select one answer).

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree

- Strongly agree

10. **Tactile or visual assessment of TOF counts can reliably detect residual paralysis?**

- Yes
- No

11. **Following this intervention, how likely are you to change your practice habits in the future?**
(Please select only one answer).

- Very unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Very likely

Submit

The name of any published instrument(s) being used, a citation/reference, proof of authorization to use

- Naguib et al., 2010—A Survey of Current Management of Neuromuscular Block in the United States and Europe

Dr. Naguib has since passed away and Dr. Kopman who is the second named author has given permission. Naguib et al. questions will be used for pretest and posttest.

From: Aaron Kopman
Sent: Saturday, July 31, 2021 10:18 AM
To: Weatherington, Andrew
Subject: Re: Permission to Utilize Several Questions from 2010 Survey Questionnaire

WARNING: This email originated from outside of USF. Do **NOT** click links or attachments unless you recognize the sender and know the content is safe.

Mr. Weatherington.

Feel free to utilize the questions.

Aaron F. Kopman, M.D.

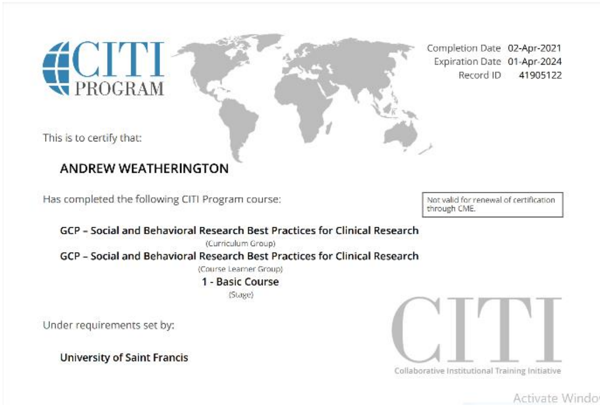
On Jul 30, 2021, at 10:55 PM, Weatherington, Andrew <WeatheringtonA@cougars.sf.edu> wrote:

Dr. Kopman,

I am Andrew Weatherington, a nurse anesthesia student at the University of Saint Francis, Fort Wayne, IN. I am in the process of developing a DNP project to increase the utilization of objective neuromuscular monitors amongst anesthesia providers when NMBA agents are administered to reduce the incidence of residual neuromuscular blockade. Is it possible to utilize some of the questions from your 2010 article by Naguib et al. "A Survey of Current Management of Neuromuscular Block in the United States and Europe?" If so, do I have your permission to make adaptations to the questions to fit the specific practice setting where the project will be implemented? I recently found out that Dr. Naguib is no longer with us and I wanted to reach out to you for permission. Thank you for your time.

Andrew Weatherington, SRNA
WeatheringtonA@cougars.sf.edu
765-401-0005

Appendix D.


Completion Date 02-Apr-2021
Expiration Date 01-Apr-2024
Record ID 41905122

CITI PROGRAM

This is to certify that:

ANDREW WEATHERINGTON

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

GCP – Social and Behavioral Research Best Practices for Clinical Research
(Curriculum Group)
GCP – Social and Behavioral Research Best Practices for Clinical Research
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

University of Saint Francis

CITI
Collaborative Institutional Training Initiative


Completion Date 02-Apr-2021
Expiration Date N/A
Record ID 41905120

CITI PROGRAM

This is to certify that:

ANDREW WEATHERINGTON

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Information Privacy Security (IPS)
(Curriculum Group)
Researchers
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

University of Saint Francis

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w89d7ac5c-dbbe-4df3-84b3-c6ccfa940f19-41905120


Completion Date 13-Apr-2021
Expiration Date 12-Apr-2024
Record ID 41905121

CITI PROGRAM

This is to certify that:

ANDREW WEATHERINGTON

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Social and Behavioral Responsible Conduct of Research
(Curriculum Group)
Social and Behavioral Responsible Conduct of Research
(Course Learner Group)
1 - RCR
(Stage)

Under requirements set by:

University of Saint Francis

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w4fa2104c-b9e1-420f-af9b-98470892bf2d-41905121


Completion Date 02-Apr-2021
Expiration Date 01-Apr-2024
Record ID 41905122

CITI PROGRAM

This is to certify that:

ANDREW WEATHERINGTON

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

GCP – Social and Behavioral Research Best Practices for Clinical Research
(Curriculum Group)
GCP – Social and Behavioral Research Best Practices for Clinical Research
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

University of Saint Francis

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?we42df35c-1bc1-442c-b3a4-424b18604eeb-41905122


Completion Date 02-Apr-2021
Expiration Date 01-Apr-2024
Record ID 41905123

CITI PROGRAM

This is to certify that:

ANDREW WEATHERINGTON

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Public Health Research
(Curriculum Group)
Public Health Research
(Course Learner Group)
1 - Basic
(Stage)

Under requirements set by:

University of Saint Francis

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w8d96f631-c151-4ef7-9ef4-df0cb4539407-41905123

Appendix E.

MARION GENERAL HOSPITAL MGH

September 13, 2021

To the University of Saint Francis Institutional Review Board:

This letter is being written in support of University of Saint Francis NAP/DNP Andrew Weatherington's Doctor of Nursing Practice Project Scholarly Project entitled "Increasing the Perceptions and Understanding of Objective Neuromuscular Monitors Amongst Anesthesia Providers." Marion General Hospital understands that the aims of the DNP Scholarly Project are to reduce the risk of residual neuromuscular blockade in those at high risk for residual neuromuscular blockade.

Marion General Hospital is supportive of the aims of the project. Marion General Hospital will allow Andrew Weatherington's to present an educational intervention to our perioperative staff, as well as collect a pre-intervention survey and 2 post-intervention surveys.

Marion General Hospital is committed to facilitating the implementation of Andrew Weatherington's DNP Scholarly Project "Increasing the Perceptions and Understanding of Objective Neuromuscular Monitors Amongst Anesthesia Providers. " No Marion General Hospital IRB is needed for this project.

Sincerely,

X Brandon Scott

Brandon Scott

MGH Surgical Dept. Administrator

441 N. Wabash Avenue | Marion, IN 46952-2690 | Telephone (765) 660-6000 | www.mgh.net

Appendix F.

University of Saint Francis

INFORMED CONSENT FORM

Project Title: Increasing the Perception and Understanding of Objective Neuromuscular Monitors Amongst Anesthesia Providers.

Project Manager: Name: Andrew Weatherington

Introduction and explanation of the purpose of the project.

I am a student registered nurse anesthetist (SRNA) at the University of Saint Francis in Fort Wayne, IN, and the DNP Faculty Advisor for this project is Dr. Keith Cotrell. As part of my Doctoral of Nursing Project, I will be presenting an educational presentation on increasing the perception and understanding of quantitative (objective) neuromuscular monitors amongst anesthesia providers. Your participation would be greatly appreciated, as the goal of this project is to increase patient safety by preventing the incidence of residual paralysis after the administration of neuromuscular relaxants.

- It will take less than 5 minutes to complete the demographic survey and pretest.
- It will take 20 minutes for the educational presentation and less than 5 minutes for the posttest.
- It will take approximately 10 minutes to complete a hands-on demonstration of the objective neuromuscular monitors.
- Following the education intervention and hands-on demonstration, you are encouraged to utilize or trial the objective neuromuscular monitors for two weeks and to complete a post evaluation survey afterwards.
- The goal is to have as many anesthesia providers participate in the surveys and presentation in anticipation of enhancing the perception and understanding of quantitative (objective) neuromuscular monitors.

Explanation of the risks and benefits of the project.

- You will not be compensated for your participation in this project. However, there is the benefit of learning how to utilize objective neuromuscular monitors for improved patient outcomes.
- There are no foreseeable risks associated with participating in this project.

Confidentiality.

- Survey responses are anonymous.
- Participation is voluntary.
- Analyzed data from the surveys will only be shared amongst those involved in the project.

Freedom to Withdraw.

- Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled.
- You may withdraw at any time from the project for any reason, without consequence or penalty.
- If a participant has only completed the pre-test, and not the presentation and posttest survey. Their survey will still be analyzed amongst the rest of the surveys.

Offer to Answer Inquiries.

Once the project has come to completion, we would be delighted to share the results with you. In the time being, if you have any questions, please contact us at:

Andrew Weatherington
University of Saint Francis
2701 Spring Street
Fort Wayne, Indiana 46808
765-401-0005
WeatheringtonA@cougars.sf.edu

If you have any complaints about your treatment as a participant in this project, please call or write:

IRB Chairperson
University of Saint Francis
2701 Spring Street
Fort Wayne, Indiana 46808
(260) 399-7700
Administration email: irb@sf.edu

I have received an explanation of this study and agree to participate. I understand that my participation in this study is strictly voluntary.

Name ____ Date _____________________

This research project has been approved by the University of Saint Francis' Institutional Review Board for the Protection of Human Subjects for a one-year period.

Appendix G.

Understanding Objective Neuromuscular Monitors Survey Tool

Please rate your agreement with each of the following statements.

1. Residual neuromuscular blockade is a problem that impacts patient care outcomes in anesthesiology?

- Strongly agree
- Agree
- Neither
- Disagree
- Strongly Disagree

2. I received adequate information on the operation of the GE Datex-Ohmeda neuromuscular monitor?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

3. I am now confident that I know how to fully utilize the GE Datex-Ohmeda neuromuscular monitor?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

4. Estimate how many times you have used the GE Datex-Ohmeda monitor.

5. How confident are you to apply the monitor?

- Extremely confident
- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

6. How confident are you in calibrating the monitor?

- Extremely confident

- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

7. How confident are you in utilizing the train-of-four ratio stimulation mode?

- Extremely confident
- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

8. How confident are you in interpreting the monitor values for train-of-four ratio stimulation?

- Extremely confident
- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

9. How confident are you in adjusting the stimulation current?

- Extremely confident
- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

10. How confident are you in changing the automatic time interval for stimulation?

- Extremely confident
- Somewhat confident
- Neutral
- Somewhat not confident
- Extremely not confident

11. How confident are you in troubleshooting the GE Datex-Ohmeda monitor?

- Extremely confident
- Somewhat not confident
- Neutral
- Somewhat confident
- Extremely not confident

12. How much does time set up and calibration factor into not using the monitor?

- Unlikely
- Neutral
- Likely

13. How much does change in anesthesia workflow for induction (forget to apply and calibrate) affect your decision not to use monitor?

- Unlikely
- Neutral
- Likely

14. How much does positioning of the patient affect your decision not to use monitor?

- Unlikely
- Neutral
- Likely

15. How much does the monitor returning values inconsistent with the clinical signs of muscle relaxation affect your decision not to use the monitor?

- Unlikely
- Neutral
- Likely

Submit

Dunworth et al., 2018, will be used as a survey following the two week trialing period to evaluate anesthesia providers understanding and utilization.

From: Dunworth, Brent <brent.dunworth@vumc.org>
Sent: Monday, August 2, 2021 8:57:23 AM
To: andrew weatherington <aweatheringt@outlook.com>
Cc: Weatherington, Andrew <WeatheringtonA@cougars.sf.edu>
Subject: Re: Permission to Utilize Survey Questionnaire for DNP Project

WARNING: This email originated from outside of USF. Do **NOT** click links or attachments unless you recognize the sender and know the content is safe.

Absolutely, Andrew, you may use it. Thanks for your work to advance this important topic.

Brent

Brent Dunworth, DNP, MBA, APRN, CRNA, NEA-BC
Assistant Professor of Clinical Anesthesiology
Director of Advanced Practice | Division Chief, Nurse Anesthesia
Department of Anesthesiology | Vanderbilt University Medical Center
4648 The Vanderbilt Clinic | 1301 Medical Center Drive | Nashville, TN 37232

615-343-6336 phone
615-343-1966 fax

Assistant: Lexi Davis

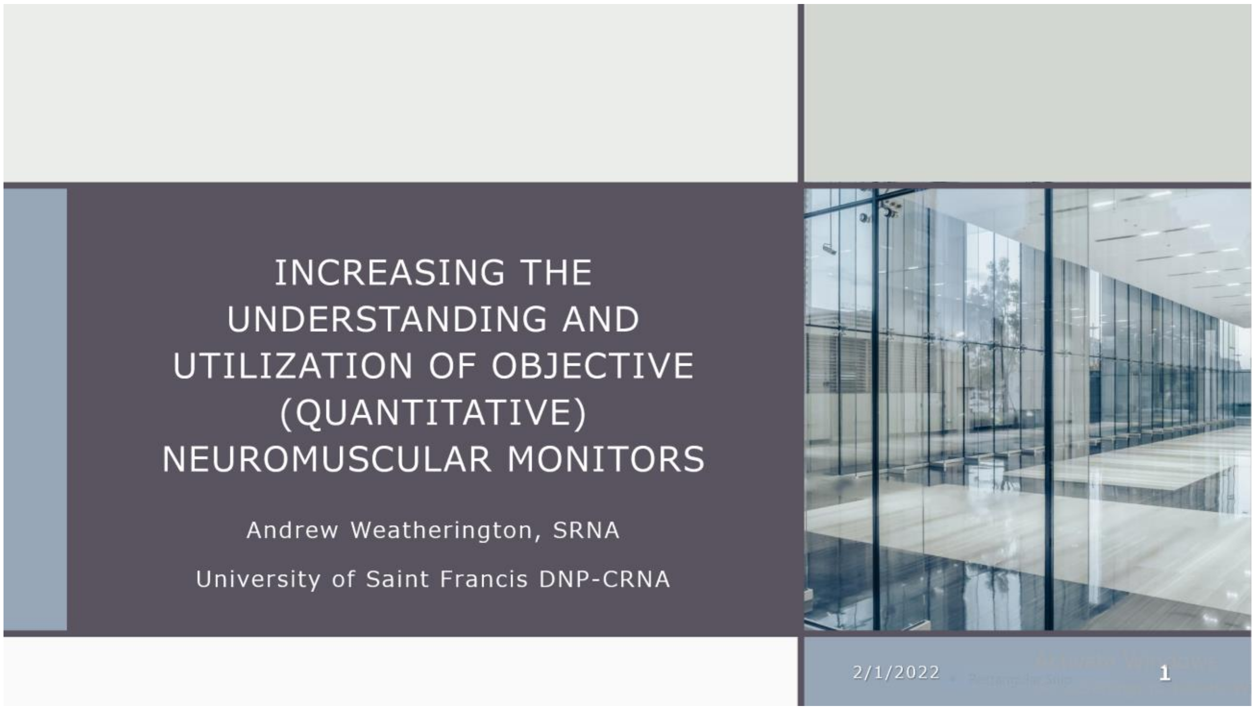
From: andrew weatherington <aweatheringt@outlook.com>
Sent: Saturday, July 31, 2021 3:28 PM
To: Dunworth, Brent <brent.dunworth@vumc.org>
Cc: Weatherington, Andrew <WeatheringtonA@cougars.sf.edu>
Subject: Permission to Utilize Survey Questionnaire for DNP Project

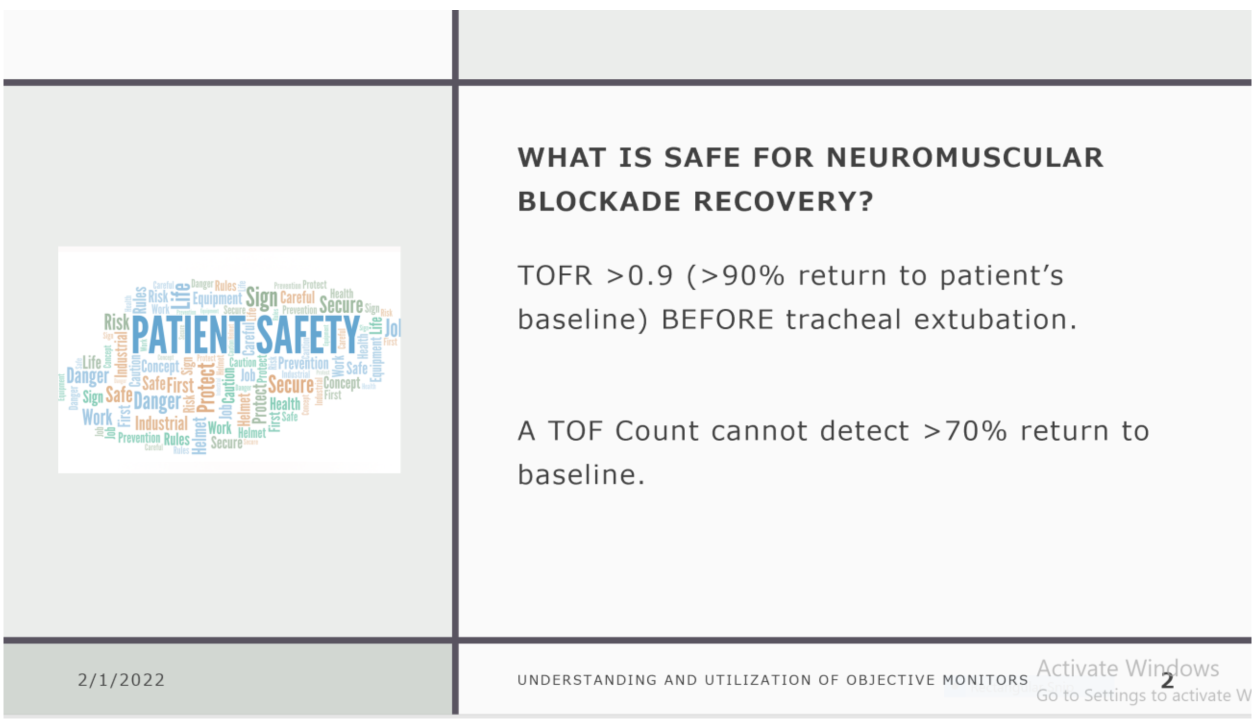
Dr. Dunworth,

I am Andrew Weatherington, an SRNA with the University of Saint Francis in Fort Wayne, Indiana. My DNP Project is “Increasing the Understanding and Utilization of Quantitative Neuromuscular Monitors Amongst Anesthesia Providers.” As such, I would like to see if it were possible to utilize a survey questionnaire from an article that you headed titled, “Implementation of Acceleromyography to Increase Use of Quantitative Neuromuscular Blockade Monitoring: A Quality Improvement Project.” The questionnaire is able to quantify the anesthesia providers understanding of quantitative neuromuscular monitors after implementation and is a great tool for limiting bias associated with self-reporting using Likert Scales, etc. Thank you for your time.

Appendix H.

Educational PowerPoint Presentation





Why Go Blind When You Can See?

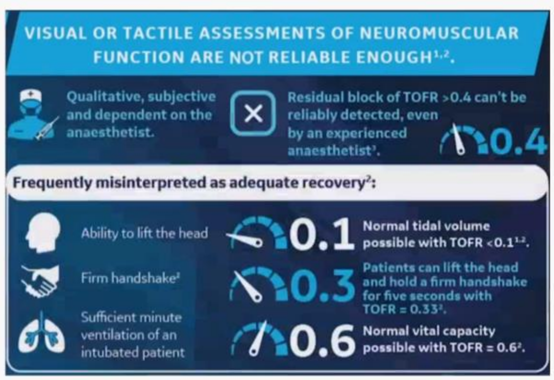
Peripheral Nerve Stimulator (Subjective monitoring)

GE Datex-Ohmeda (Objective Monitoring)

What About "The Old Standby's?"

Subjective Measurements

- 5-second head lifts
- Hands grasps
- Tidal Volume
- Negative inspiratory force
- Teeth clenching



http://scientific-culture.blogspot.com/2012/11/sunday.html

https://www.houstonswimclub.com/2019/08/Dry-drowning...what-does-that-even-mean

RESIDUAL NEUROMUSCULAR BLOCKADE, A PROBLEM?

The incidence of RNMB at **31-40.5%** based on objective neuromuscular monitoring.

A **single intubating dose of Rocuronium lasted 2 hours** in 37% of patients.

Morbidity

Incidence

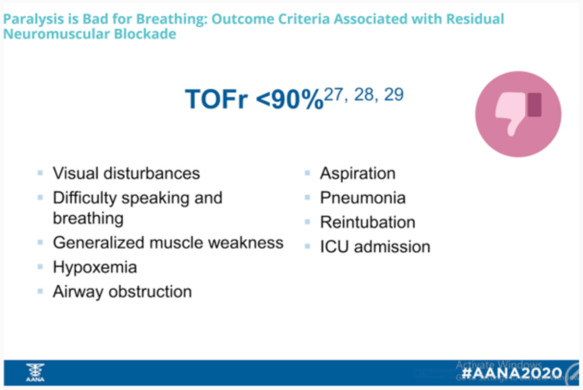
Carry a significantly increased risk of **morbidity** and **mortality** for patients.

Residual Neuromuscular Blockade

UNDERSTANDING AND UTILIZATION OF OBJECTIVE MONITORS

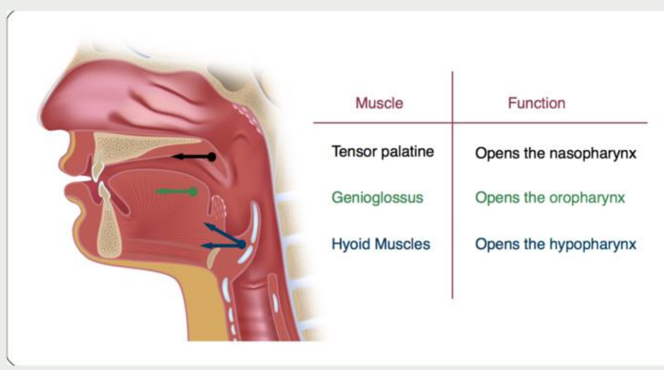
2/1/2022

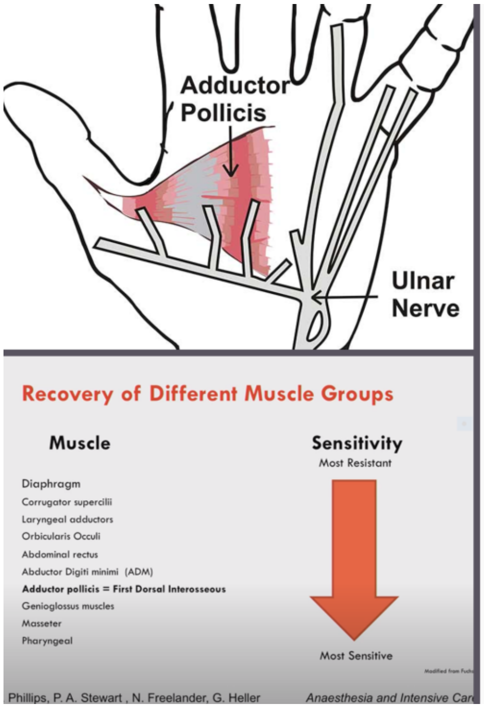
6



WHAT DOES A TOFR <0.9 LOOK LIKE?

Pharyngeal Muscles Are The Most Sensitive To NMBAs and Last To Return



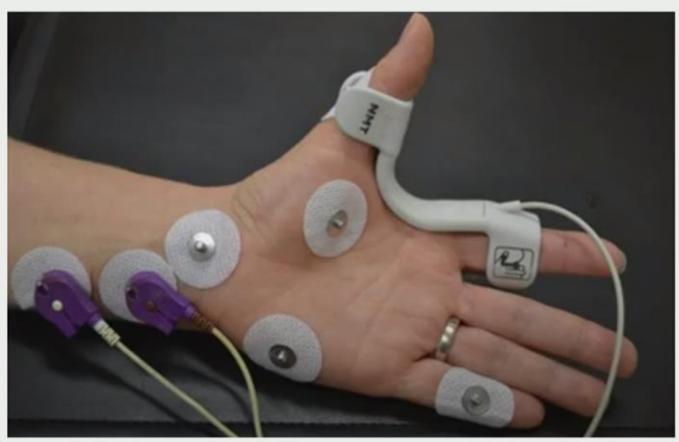


Safest Practice To Reduce Residual Neuromuscular Blockade

- Use of Objective Monitor When Available is Best Method of Recovery.
- Adductor Pollicis Best Correlates With Pharyngeal Muscles Recovery & TOFR >0.9.

2/1/2022 9

THANK YOU

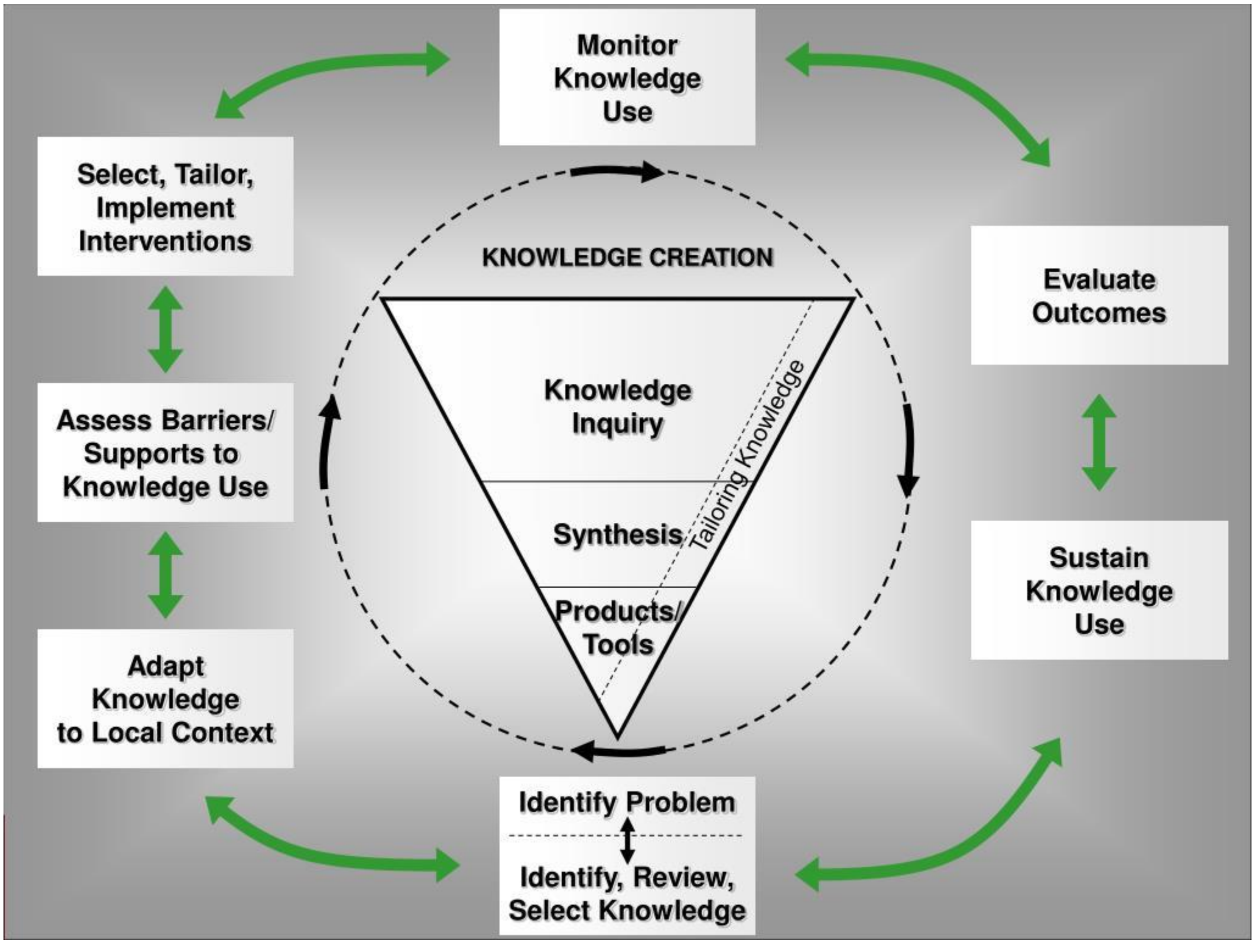


2/1/2022

UNDERSTANDING AND UTILIZATION OF OBJECTIVE MONITORS 10

Appendix I.

KTA Framework (Strauss et al., 2011)



Appendix J.

University of Saint Francis
Institutional Review Board
Human Subjects Review Committee/ACUC/IBC
Institutional Review Board Approval Form

Protocol Number: 16325986792
Reviewed by (underline one): HSRC ACUC IBC
Date Reviewed: Monday, January 24, 2022
Principal Investigator: Andrew Weatherington
Faculty Advisor: Dr. Keith Cotrell
Protocol Title: Increasing Understanding of Objective Monitors
Study Site(s): University of Saint Francis, Main Campus

Type of Proposal:
☐Original research
☐ Replication or extension of previous research
☒Quality Improvement/Evidence-Based Practice Project

Items submitted for review:
☒CITI Certificate
☒Initial protocol
☐Abstract
☒Informed Consent Form (if applicable)
☒Approval letter from outside institution
☐Other – explain: Email request was made for waiver

Type of Review:
☒Full Review
☐Expedited Review
☐Exempt Review

Approval:
☒Approval granted on Monday, January 24, 2022 for a period of one year.
☐Conditional approval* granted on ____________________ for a period of one year.
☐Not approved*
☐IRB approval is not required:
☐Other

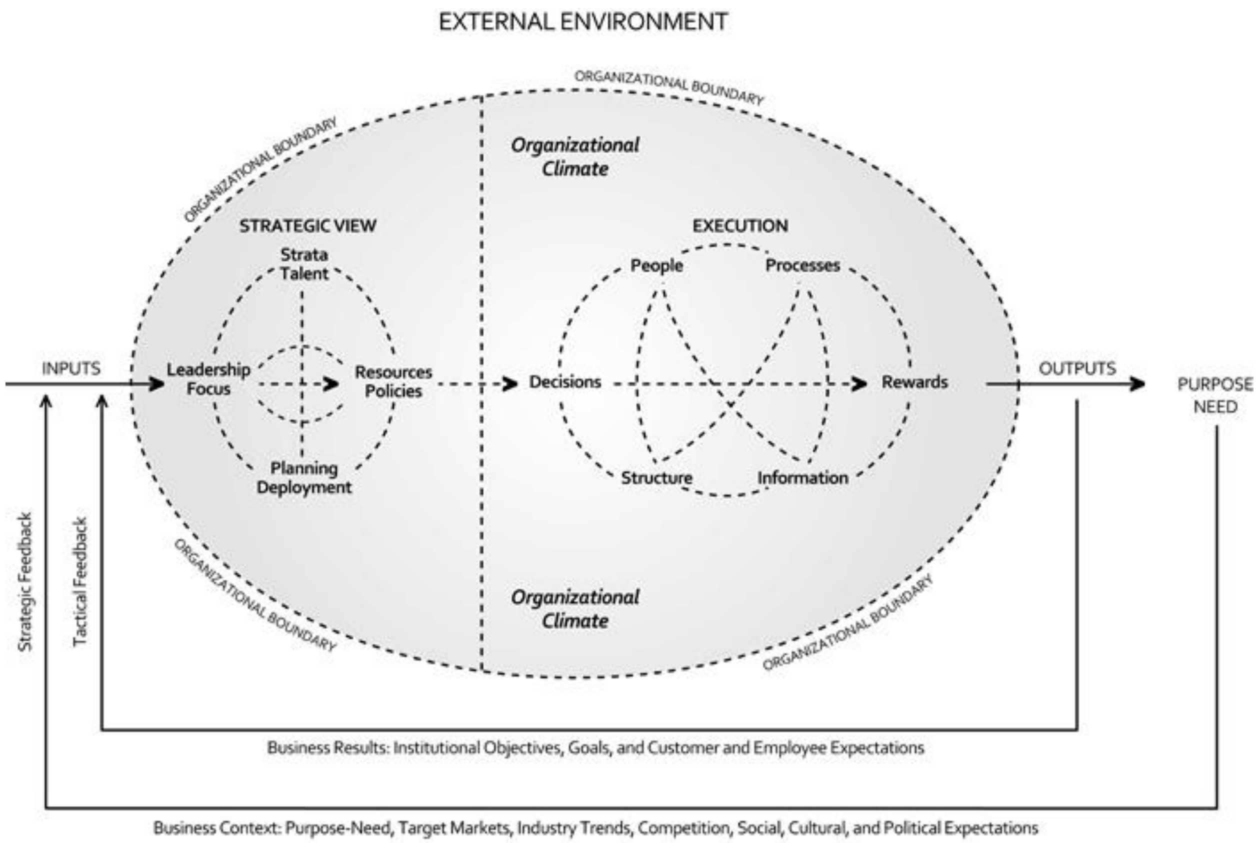
*Comments:

The committee performing this review is duly constituted and operates in accordance and compliance with local and federal regulations and guidelines.

Michael P. Bechill, IRB Chair	Michael P. Bechill	2022-01-24
Printed Name (Chair or designee)	Signature	Date

Appendix K.

Open Systems Model (Breckenridge Institute, 2016).



Appendix L.

Twitch View Train of Four Monitor by Blink Device Company

Tables

Table 1

Project Timeline

PROJECT NAME	PROJECT START DATE	PROJECT END DATE	PROJECT DURATION
Increasing Objective Monitors Utilization Among Anesthesia Providers	1/9/2021	6/15/2022	

Task	Start	End	Duration	January	Feburary	March	April	May	June	July	August	September	October	November	December	Janurary	Feburary	March	April	May	June
Comprehensive Lit. Review	1/9/2021	1/24/2021	15 days																		
Synthesis of Literature	1/25/2021	2/14/2021	10 days																		
Gap Analysis	3/7/2021	3/23/2021	16 days																		
CITI Training	3/23/2021	4/18/2021	26 days																		
Project Agreement Signed	4/18/2021	4/25/2021	7 days																		
Organizational Assessment	5/8/2021	5/30/2021	22 days																		
SWOT Analysis	5/15/2021	5/30/2021	15 days																		
Force Field Analysis	5/30/2021	6/6/2021	7 days																		
DNP Project Budget	6/12/2021	6/20/2021	8 days																		
Meeting w/Practice Advisor	6/20/2021	7/1/2021	11 days																		
Meeting w/ Practice Mentor	6/20/2021	7/1/2021	11 days																		
Creation of Informed Consent	6/26/2021	7/10/2021	14 days																		
USF IRB Approval	8/26/2021	9/26/2021	30 days																		
Hospital IRB Approval	9/26/2021	10/26/2021	30 days																		
Implementation	11/15/2021	2/15/2022	60 days																		
Analyze Results	2/15/2022	4/30/2022	75 days																		
Enter data into SPSS	2/15/2022	3/1/2022	15 days																		
Completion of Executive Summar	4/30/2022	5/15/2021	15 days																		
Completion of DNP Manuscript	4/30/2022	5/30/2022	30 days																		
Dissemination of Findings	5/30/2022	6/15/2022	15 days																		

Figures

Figure 1

Post-test Question #1

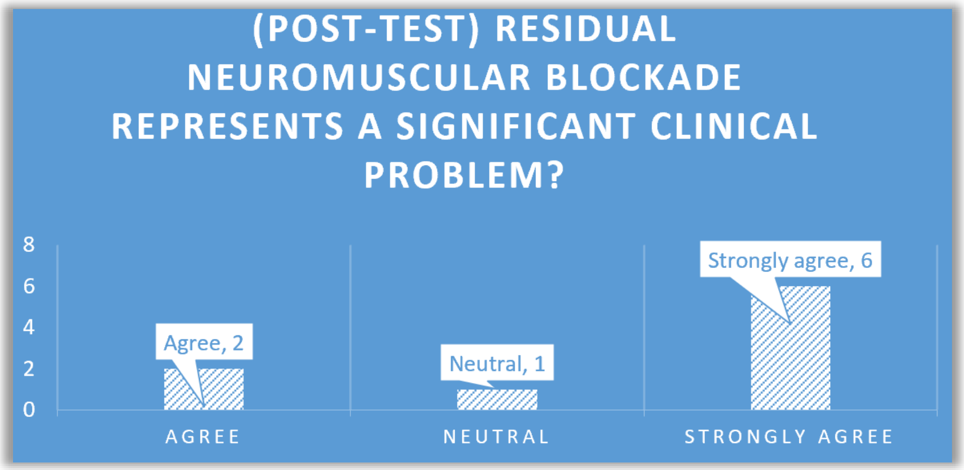


Figure 2

Pretest Question #3

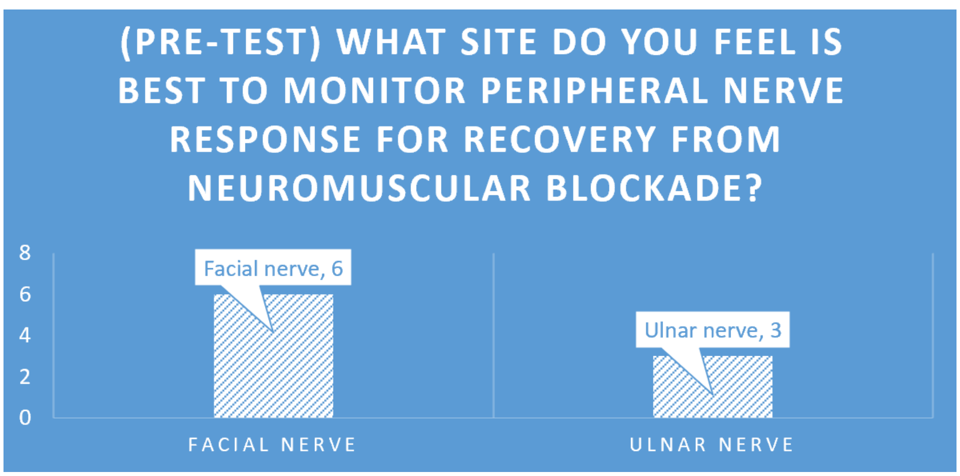


Figure 3

Pretest Question #4

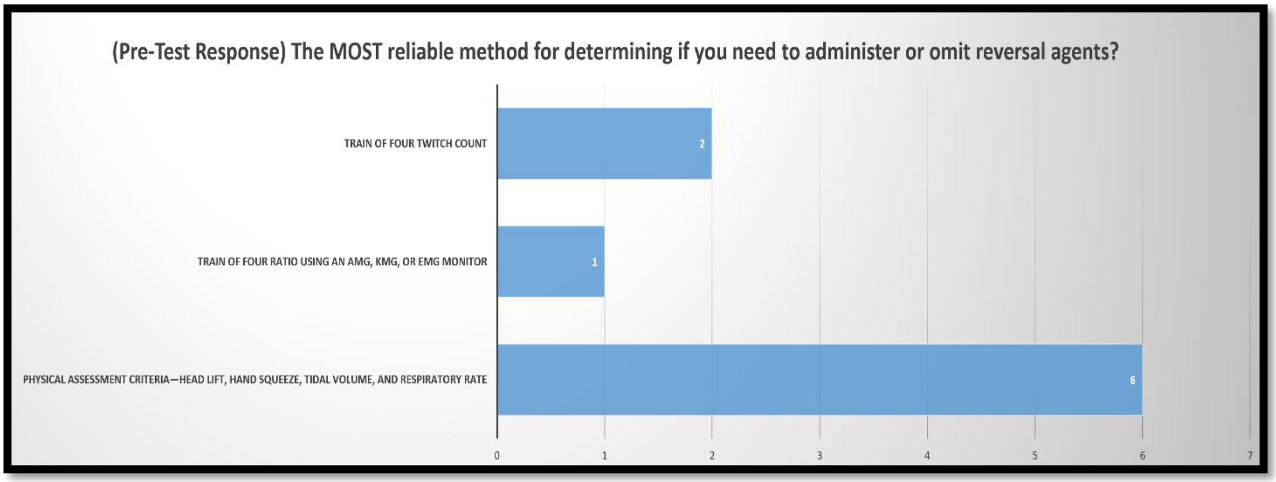


Figure 4

Post-test Question #2

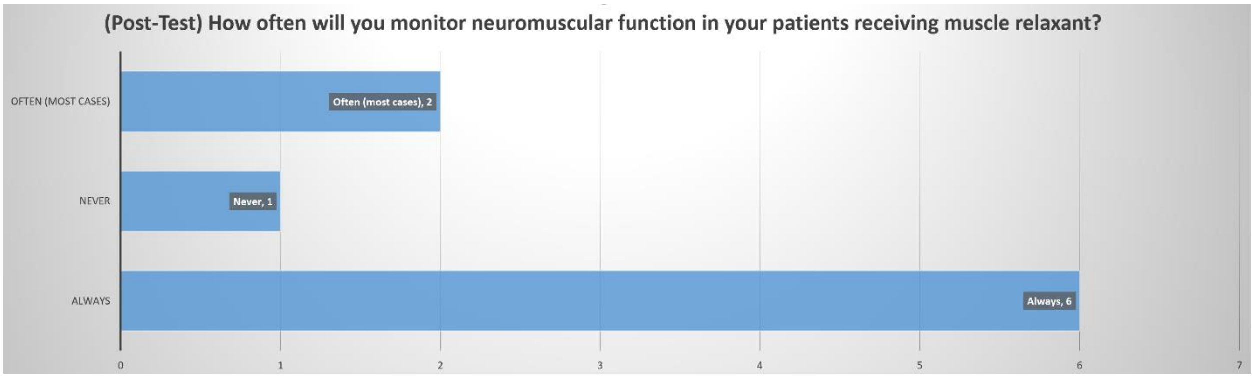


Figure 5

Post-test Question #11