DEVELOPMENT OF A CLINICAL PRACTICE GUIDELINE FOR MONITORING NEUROMUSCULAR BLOCKADE

by

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As members of the DNP Project Committee, we certify that we have read the DNP project prepared by *Austin Roy Thruston*, titled *Development of a Clinical Practice Guideline for Monitoring Neuromuscular Blockade* and recommend that it be accepted as fulfilling the DNP project requirement for the Degree of Doctor of Nursing Practice.

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Final approval and acceptance of this DNP project is contingent upon the candidate's submission of the final copies of the DNP project to the Graduate College.

I hereby certify that I have read this DNP project prepared under my direction and recommend that it be accepted as fulfilling the DNP project requirement.

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DEDICATION

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ABSTRACT

After neuromuscular blockade is achieved in the surgical setting, it is important that the patient obtain adequate recovery. If the patient is extubated and sent to the post-anesthesia care unit without adequate recovery, there is a higher incidence of respiratory complications. Newer technology has made objective neuromuscular junction monitoring more available and affordable than in the past. The purpose of this Doctor of Nursing Practice (DNP) project was to develop a clinical practice guideline (CPG) to assist practitioners in monitoring residual paralysis. As a theoretical framework, Lewin's Change Theory and the Knowledge to Action Framework was used to move current research into practice. Expert opinion was acquired to assist in the development of a CPG. The CPG was then appraised by four anesthesia providers to ensure that a high-quality CPG, ready for implementation, was developed. The CPG was appraised using the Appraisal of Guidelines for Research & Evaluation II (AGREE II) assessment platform. The results were clear that the CPG exceeded the 70% required to ensure a high-quality CPG with the scores for each domain ranging from 92% to 98%. All appraisers stated they would recommend the CPG for implementation into practice.

INTRODUCTION

Background Knowledge

Current Practice

According to the United States Department of Health and Human Services, there are over 40 million surgical procedures performed in the United States every year (Hall, Schwartzman, Zhang, & Liu, 2017). To provide a safe surgical field for the patient and the procedure, the anesthesia provider is often required to use medications to inhibit neuromuscular transmission to prevent movement during surgical manipulation. Once the procedure is complete, it is imperative for the anesthesia provider to assess the amount blockade present and ensure the patient has regained adequate neuromuscular function before moving the patient to the post-anesthesia care unit (PACU). When a typical monitor utilizing subjective data is used to monitor the level of paralysis, the incidence of residual paralysis is as high as 40% in patients entering the PACU (Brull et al., 2008). The lack of monitoring for residual paralysis can lead to serious respiratory complications, decreased patient satisfaction, postoperative pneumonia, and even death (Brull et al., 2008). In 2014, the average surgery in the United States costs $5,015. This cost goes up to $62,704 when there are postoperative respiratory complications. The American Association of Nurse Anesthetists (AANA) provides standards for practice which state “when neuromuscular blocking agents are administered, monitor neuromuscular response to assess the depth of block and degree of recovery” (American Association of Nurse Anesthetists, 2017). The physician anesthesia professional organization, the American Society of Anesthesiologists’ standards do not require the use of a neuromuscular monitor even in the presence of neuromuscular blockade (NMB) (American Society of Anesthesiologists, 2017). The two associations standards fall short

in providing a guideline for recommendations based on current evidence that supports using a train of four(TOF) ratio of >0.9 as the gold standard to ensure adequate recovery, using an objective measure to assess the TOF ratio, and excluding subjective measures that have been proven ineffective. (Plummer-Roberts, Trost, Collins, & Hewer, 2016).

Definition of Terms

Residual Paralysis

After the anesthesia provider administers a neuromuscular blocking drug the patient becomes paralyzed to enhance the surgical field. When the paralytic is no longer needed, the patient receives a reversal drug to eliminate the paralysis. Complete reversal and readiness for extubation is determined by a TOF ratio of > 0.9 (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). When this number is not achieved, the patient is said to have residual paralysis.

Train-of-Four Ratio

Using a nerve stimulator, the anesthesia provider delivers four separate stimuli every 0.5 seconds and a frequency of 2 Hz. A comparison is then made regarding the size of the fourth twitch to the size of the first twitch (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). The TOF ratio is equal to the size of the fourth twitch divided by the size of the first twitch. The TOF ratio falls within range of 0.9 and 1.0, and the implications of these ratios are described in further detail below.

Objective Monitoring

Quantitative monitoring that displays a TOF ratio where the stimulator is coupled with a transducer and a number value is displayed.

Significance

The Neuromuscular Junction

The neuromuscular junction plays an important role in how neuromuscular blocking drugs allow for improved airway access and operative field optimization during surgery. Acetylcholine (ACh) is the neurotransmitter that is released from the presynaptic cleft and binds to the nicotinic cholinergic receptor on the motor end plate which opens an ion channel allowing for potassium to exit while sodium and calcium enter (Butterworth, Mackey, & Wasnick, 2013). This movement of ion creates an action potential along the muscle membrane, which results in a muscle contraction. Neuromuscular blocking medications will inhibit this action affording muscle relaxation when needed. In order for patients to recover from these drugs, it is important to measure the degree of relaxation and administer an antidote to reverse the relaxation.

Monitoring Neuromuscular Blockade

According to the American Association for Nurse Anesthetists (AANA), the standard of care is to monitor neuromuscular response when utilizing a NMB drug (American Association of Nurse Anesthetists, 2017). It does not state how often it should be measured, what kind of device to use, what measurement determines safety to reverse, or what measurement means it is safe to remove the endotracheal tube. In many operating rooms, only subjective, either visual or tactile, evaluations determine if adequate reversal has taken place and it is safe to extubate (Brull & Kopman, 2017). Several studies have concluded that the only method to accurately determine if adequate reversal has taken place and it is safe to extubate is by using an objective measuring device that reveals a train-of-four ratio (TOF) of greater than 0.9 measured at the adductor pollicis via the ulnar nerve (Brull & Kopman, 2017). For this reason, the absence of this

recommendation in either of the current professional standards for monitoring falls short in protecting patients from residual neuromuscular blockade.

As stated above, the TOF ratio of >0.9 is the only reliable measure to determine if adequate reversal has occurred. To obtain the ratio a peripheral nerve stimulator must be used to deliver four electrical stimuli of 2 Hertz every 5 seconds. The TOF ratio can be calculated by comparing the first twitch to the fourth twitch (Figure 1). If the fourth twitch is half of the first, the TOF ratio is 0.5. At a ratio of 0.5 the patient can lift their head for 5 seconds, but cannot adequately protect their airway. Even at a TOF ratio of 0.8 there is still risk for impaired swallowing and aspiration risk (Hammermeister, Bronsert, Richman, & Henderson, 2016). Research has shown that subjective measures to obtain a TOF ratio cannot determine the difference between a TOF ratio of 0.4 and 0.9 and that only objective measures can adequately determine adequate reversal (Viby-Mogensen et al., 1985). Research has also shown that commonly taught subjective measures such as grip strength, head lift, and adequate tidal volume are not reliable in detecting residual blockade (Brull & Kopman, 2017).

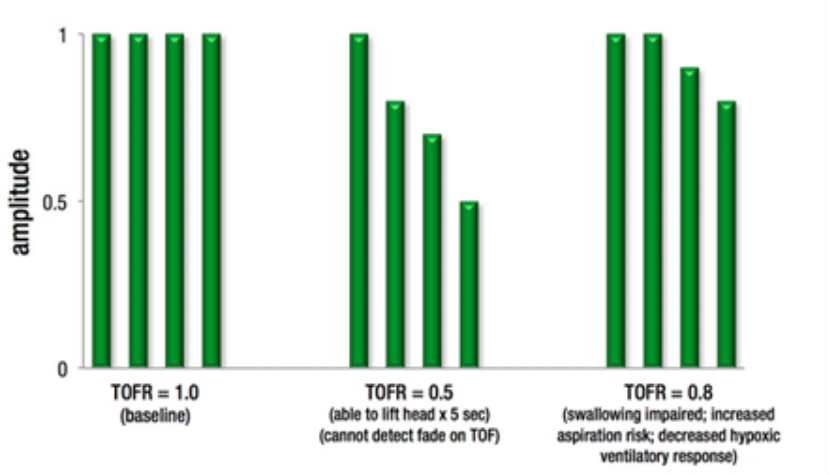
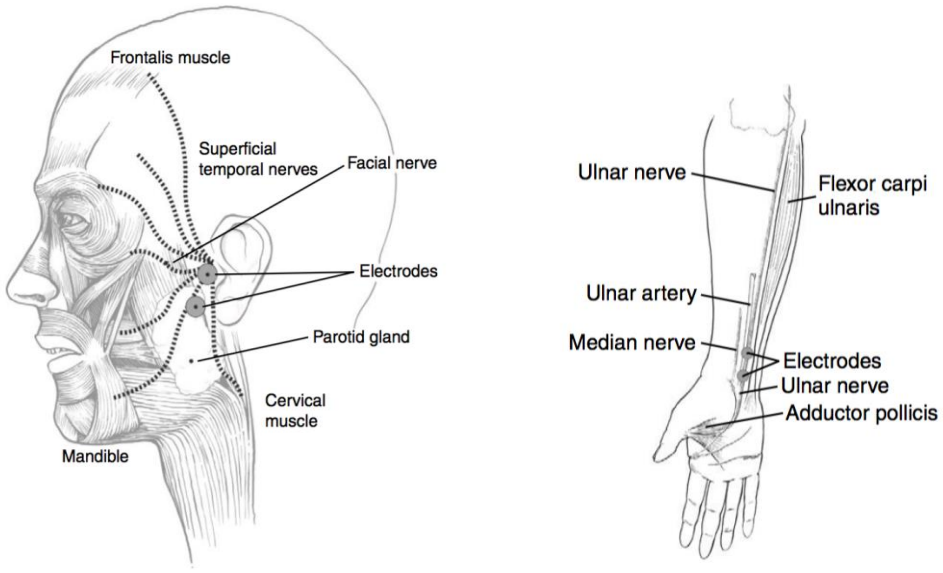


FIGURE 1. Train-of-four ratios. (Hammermeister, Bronsert, Richman, & Henderson, 2016)

The site of monitoring is also an important factor when determining the amount of residual blockade. The preferred site to monitor muscle contraction from the nerve stimulator is by placing two electrodes over the ulnar nerve (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014) (Figure 2). When stimulation from the nerve stimulator is delivered to the electrodes, adduction of the thumb can be visualized to determine the TOF ratio. One problem with this site is that is often out of reach to the anesthesia provider or under the sterile drape. In this situation, the facial nerve is often evaluated and twitches are evaluated by eyelid movement. Due to distribution and blood flow, the eyelid is best to determine the onset of the drug. However, this is not true for the recovery where the ulnar nerve correlates to recovery of the diaphragm (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). This is another reason why simple subjective measures are not adequate to assess recovery.



a) Facial Nerve *b) Ulnar Nerve*

FIGURE 2. Neuromuscular monitoring sites. (Nagelhout, Neuromuscular Blocking Agents, Reversal Agents, and their Monitoring., 2014)

The most common peripheral nerve stimulator used is a hand-held device that has two electrodes, that are placed on the nerve to create contraction. The two muscles used to assess TOF ratio are the adductor pollicis via the ulnar nerve and the orbicularis oculi via the temporal branch of the facial nerve. The TOF button is set to deliver 50 Hz of current and eyelid movement is observed to assess the ratio. The facial nerve is the most common site because the anesthesia provider usually has easy access to the patient's face. However, this indicator only provides the provider with unreliable subjective data. Multiple objective nerve stimulators provide an actual reading of TOF ratio that take clinician error out of the equation. The gold standard is mechanomyography (MMG), however, this is a very cumbersome device and not practical in every clinical setting (Plummer-Roberts, Trost, Collins, & Hewer, 2016). Another is an objective measure that is accurate and practical is acceleromyography (AMG) (Figure 3). The AMG will be used as a reference for this paper based on its accuracy and availability. When patients enter the post-anesthesia care unit (PACU) after using the AMG only 4% of them have a TOF ratio of <0.9. When the subjective monitor is used, the incidence of residual paralysis is as high as 40% in patients entering the PACU (Brull et al., 2008). The ulnar nerve is the easiest and most accurate way to assess a TOF ratio and determine if the patient will not have residual paralysis. There are procedures when the arms are tucked and there is no access to the ulnar nerve. In this situation, the accelerometer may be placed on the face using double sided tape to monitor twitches from the facial nerve.

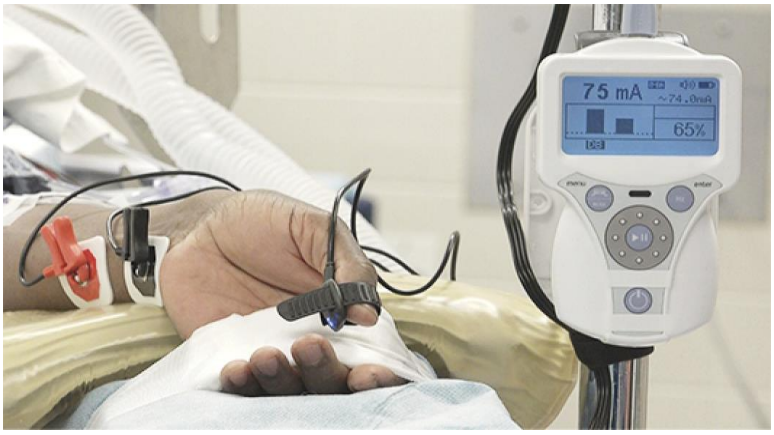


FIGURE 3. STIMPOD NMS450 acceleromyography on the ulnar nerve. (Ortega et al., 2018)

Reversal of neuromuscular blockade. Once a procedure is completed and there is no longer a need for NMB, the anesthesia provider has the option to give a classification of neuromuscular junction reversal drugs known as acetylcholinesterase inhibitors. When these drugs enter the synapse, they bind to the acetylcholinesterase receptors, which prevent the breakdown of ACh (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). This action increases the amount of ACh around the junction. This increases the amount of ACh that competes with the NMB to bind to the nicotinic receptor, therefore allowing the muscle to contract again. Depending on the chosen reversal drug, the number of twitches should be monitored to guide the correct dosage. Even when the appropriate number of twitches are obtained and the patient is reversed, it can still take up to 20 minutes for the TOF ratio to be >0.9 (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). It is also important to note there are side effects of giving an acetylcholinesterase inhibitor including bradycardia, arrhythmias, hypotension, diarrhea, bronchoconstriction, and post-operative nausea and vomiting (Naguib, 2015).

Another reversal drug that is new to the market is Sugammadex. This is the first reversal drug that does not affect ACh so it does not seem to have the negative effects described earlier. Another advantage is that Sugammadex can be given at a higher dose to reverse even a profound block within 3 minutes (Naguib, 2015). Some of the noted limitations include procedural hypotension, recurrence of the block, inability to reverse benzylisoquinolinium neuromuscular blockers, and most notably allergic reactions (Naguib, 2015). Although this drug is showing promising results for reversing certain NMB medications, studies are showing that objective TOF measurements are still necessary to adequately dose Sugammadex to assure adequate reversal while minimizing the adverse effects associated with the drug (Kaufhold et al., 2016).

Residual Paralysis

In the past, a TOF ratio of 0.7 was the gold standard for determining if residual paralysis was present and would lead to complications (Viby-Mogensen et al., 1985). With new research into the side effects and negative outcomes associated with residual paralysis, the new standard is a TOF ratio of 0.9. In fact, the definition of residual paralysis is "a train-of-four ratio (TOFR) <0.9 at the adductor pollicis." (Donati, 2013) This was updated based on evidence that a TOF of 0.9 was necessary to ensure recovery of laryngeal function including the ability to swallow and airway protection. Another important physiologic factor is that when the TOF ratio is <0.9 the hypoxic drive can still be impaired (Donati, 2013). This is important in patients with lung disease who use oxygen chemoreceptors to regulate the respiratory cycle.

When subjective peripheral nerve stimulators are used to assess TOF ratio, the number of patients arriving in the PACU with a residual neuromuscular block in effect is reported to be as high as 40% (Brull & Kopman, 2017). This number can be greatly reduced to approximately 4%

when using objective measures to verify a TOF ratio of >0.9 before extubation (Brull et al., 2008). There is also research suggesting that duration of action of NMB drugs as cited by the manufacturer is not accurate and can far exceed the stated duration of action. This finding is due to factors that can prolong paralysis, including drug interaction, antibiotics, electrolyte abnormalities, and other pathophysiologic factors that can affect the duration of action (Nagelhout, Neuromuscular blocking agents, reversal agents, and their monitoring, 2014). Due to these many factors, the anesthesia governing boards in other countries have already updated their standard monitoring protocol. These protocols include language describing the recovery process and how to monitor it more effectively. In 2015, the Association of Anesthetists of Great Britain and Ireland added addendum #3 to their standards. These standards outline a peripheral nerve stimulator is mandatory to assess NMB, the device should be used throughout the perioperative process, return of motor function is a TOF ratio of 0.9, and most importantly a quantitative nerve stimulator is required to ensure a TOF ratio of 0.9 (Checketts M. et al., 2015).

Complications from residual paralysis. Although there are several complications that can arise when a patient is extubated with residual paralysis, defined as a TOF <0.9, the most common and dangerous effect is that on the respiratory system. Common complications include respiratory failure, upper airway collapse, inability to swallow, re-intubation, and hypoxia (Plaud, Debaene, Donati, & Marty, 2010). The evidence shows that there is a much higher percentage of critical respiratory events when the patient arrives in the PACU with a TOF ratio of <0.9. When there is noted residual paralysis, there is also a higher incidence of postoperative pneumonia (Farhan, Moreno-Duarte, Mclean, & Eikermann, 2014).

Although respiratory complications are the greatest concern, other complications are also common. Patients undergoing ambulatory surgery are often required to walk shortly after surgery. In a patient with residual paralysis, muscle weakness can affect their ability to ambulate and lead to an increased risk of falling (Farhan, Moreno-Duarte, Mclean, & Eikermann, 2014). There is also evidence suggesting the use of an AMG improves the patients' perception of their recovery and therefore their patient satisfaction scores are more positive then when using subjective measure (Plummer-Roberts, Trost, Collins, & Hewer, 2016). Both measures are directly tied to reimbursement for the provider and can affect the amount billed and received after performing the procedure. Another issue related to costs and residual paralysis is that when patients arrive in the PACU with a TOF of <0.9 their discharge times are significantly longer than those without a residual blockade. In the United States, the average costs for a surgery is $5,015, when there are postoperative respiratory complications that number rises to $62,704 (Farhan, Moreno-Duarte, Mclean, & Eikermann, 2014).

Problem Statement

There is a wide variety of methods anesthesia providers use to assess the degree of NMB present in surgical patients in the United States. While the evidence provided shows that up to 40% of patients arriving in the PACU have a TOF ratio of < 0.9, surveys have found that many current anesthesia practitioners believe that this number is less than 1% (Brull & Kopman, 2017). One way to make the measurement of neuromuscular blockade more objective is using a monitoring device that quantitatively measures the TOF ratio. In other countries, anesthesia governing boards have adopted standards which include the use of TOF ratio and objective monitors. However, two U.S. professional anesthesia associations, American Society of

Anesthesia and American Association of Nurse Anesthetists, have not updated their standards to incorporate this new monitoring technology to improve patient safety. As a result of not using an AMG, patients face a higher risk of developing postoperative complications which can be detrimental and costly to the patient, provider, and facility.

Study Purpose

The purpose of this project was to use information gathered by expert clinical providers to create a CPG and then evaluate a new CPG for a local anesthesia group via a systematic process. The intent was to develop a local CPG whereby residual neuromuscular blockade is prevented by assuring a TOF ratio of > 0.9 is achieved on all patients receiving NMB medications. This project aimed to gather data about current practice habits, attitudes, and beliefs regarding neuromuscular blockade management via personal interviews with expert anesthesia personnel who assisted in the guideline development and evaluation. This project aimed to answer the following question: At this anesthesia group, will the development of a CPG with input by facility stakeholders lead to the formulation of a high scoring CPG regarding the management of NMB as determined by the AGREE II tool?

THEORETICAL FRAMEWORK

Lewin's Change Theory

Healthcare facilities and organizations have policies and behaviors that are specific to each one of them. Many of these policies are out of date and do not reflect current evidence. It is estimated that up to 45% of patients are receiving care that does not correspond with current evidence (Graham I. et al., 2006). Kurt Lewin's theory strives to understand and define the behaviors that the facilities, and the stakeholders, have and developed a way to try and

constructively break them down to promote new change. The model defined two forces that are in constant movement with each other; which is why the theory is also called Lewin's force field analysis. The first force is called the restraining forces that include factors that oppose change and make it more difficult. The competing force is called the driving forces. These include components that help to drive the change (Sutherland, Applying Lewin's change management theory to the implementation of bar-coded medication administration, 2013).

Lewin broke down the process of change into three phases that include the unfreezing stage, the change stage, and the refreezing stage. In the first stage, the problems are identified and the involvement of the stakeholders will begin. In this phase, there is resistance as current practice and norms are challenged. In the operating room, as evidence has shown, the current practice regarding NMB monitoring is outdated and needs to be revised. However, many of the current anesthesia providers still rely on, and are comfortable with, this practice. Barriers to this project in this phase included breaking down these norms and overcoming the resistance to change. In this phase, barriers were discussed before moving to the next step of change.

The second step in the change theory is the actual change implementation. Several stakeholders including anesthesia providers, managers, and educators were part of the development of the CPG. In this phase, the CPG was presented to the stakeholders so they understood the CPG and the benefits it would provide to their patients. There needed to be involvement from all users and available equipment necessary to assess TOF ratio needed to be present. A project leader was identified at the facility to help ensure the CPG was understood and is successfully implemented.

The third and final step in Lewin's theory was the refreezing stage. After the CPG was presented to the facility, the third phase was to make it part of the standard of care on the given unit. This took take place after all barriers and problems were resolved and stakeholders agreed that this will provide the quality of care they strive to provide for their patients. For this CPG to successfully become part of the standard of care, the facility will need ongoing support from the leader who will ensure that necessary education and equipment is always available to those who need it.

Knowledge to Action Framework

Lewin's change theory helps to identify barriers and actions that can effect change. The Knowledge to Action (KTA) framework is designed to translate current literature and CPG's into practice as fast as possible. Graham identified in research that 45% of patients are not receiving correct care, 25% of care is being given that is not needed, and outcomes could be improved by up to 30% if up to date research was incorporated into practice (Graham I. et al., 2006). To overcome this Graham and colleagues developed the knowledge to action process that incorporated what they describe as the knowledge funnel and the action cycle (Figure 4).

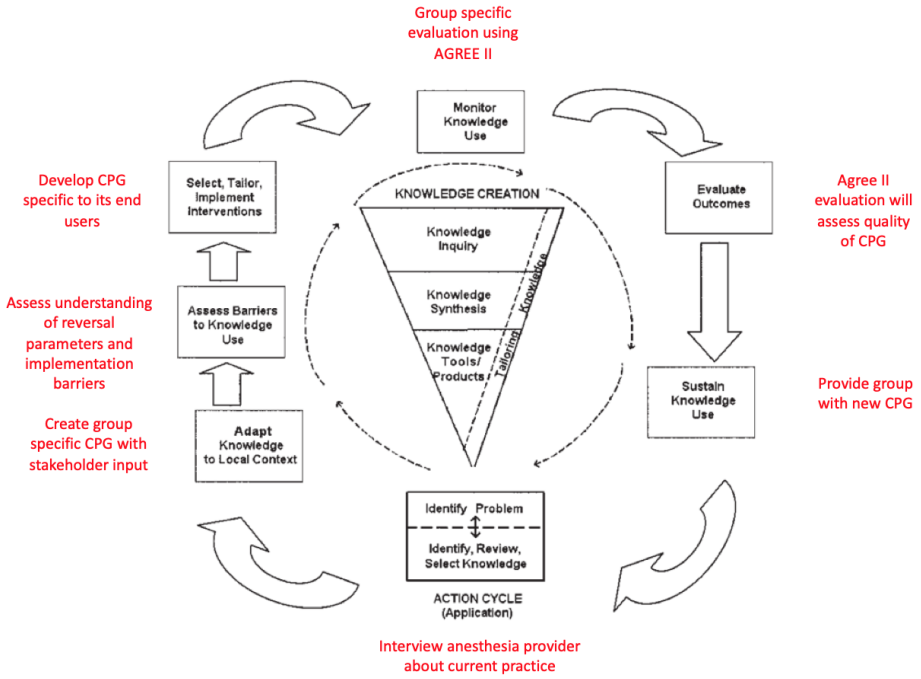


FIGURE 4. Knowledge to action process. (Graham I. et al., 2006)

The knowledge funnel is where knowledge creation happens and is transitioned to a presentable form for the given stakeholders. The first stage is known as knowledge inquiry and is where an unmanageable amount of knowledge, ideas, studies, and questions exist. It is where knowledge inquiry begins before true literature review is performed. Moving down the knowledge funnel is the knowledge synthesis section. In this stage, a literature review is performed to ensure up to date evidenced-based research supports the initial inquiry. This stage will include studies, systematic reviews, and meta-analysis if available (Graham I. et al., 2006). In the final stage of the knowledge funnel knowledge tools such as CPG's are either adopted or developed to provide a clear and concise recommendation for the stakeholders. This is where the CPG outlining reversal of NMB was established before moving on to the action and implementation stage.

Once the CPG was developed and supported by evidence, it moved into the action cycle of the KTA process. Parts of the KTA model that were used to operationalize this project were the steps in the KTA process used to identify and adapt knowledge at a local level, assess barriers, and then select and tailor knowledge which may facilitate implementation. One anesthesia provider was identified and interviewed to evaluate current provider practice regarding neuromuscular reversal and assess the applicability of a locally created CPG. Moving through the cycle, the next step of this project was to work with the anesthesia provider champion to identify any barriers that are present at the facility and use this information to tailor the CPG to this facility. Some expected barriers include the cost of purchasing objective TOF monitors, availability of monitors, and change in habits and norms. Upon completion of these steps, a local CPG for implementation was created. An aim was to evaluate the utilization of the CPG among the anesthesia practitioners and if the CPG was adopted as a standard of care for the facility.

SYNTHESIS OF EVIDENCE

Before beginning to develop a CPG that will provide guidance on when to reverse paralysis and what is the best method, an extensive literature review was completed to find the best evidence to support the need for change. There were three primary literature searches; including PubMed, Cumulative Index of Nursing and Allied Health Literature (CINAHL), and the Cochrane Library. The primary keywords used were peripheral nerve stimulation and residual neuromuscular block. Other related terms included objective monitoring, neuromuscular junction, anesthesia, and subjective monitoring. Inclusion criteria for the literature review included studies published within the last ten years, human subjects, English language, and full-

text availability. The searches yielded 27 results, 4 results, and 5 results respectively for a total of 36 primary results. Using the other defined keywords yielded several other studies used to support the evidence. For this project, ten studies met the criteria for further synthesis of evidence (Table 1).

A large systematic review, completed in 2008, determined the benefit of using an objective monitor when evaluating the ability to detect residual paralysis compared to using subjective monitoring. In this review, 38 studies met the inclusion criteria and thus utilized as evidence (Claudius & Viby-Mogensen, 2008). The study looked at four groups, each with different studies included and different levels of evidence, to determine the benefit of using objective monitoring. After careful review, it determined that there is strong evidence to support perioperative monitoring with an objective monitor to detect residual paralysis. The study also compared the standard monitoring methods to objective monitoring and determined that using tools such as an acceleromyography is more sensitive than tactile evaluation and will determine the correct TOF ratio of 0.9 over 90% of the time compared to only 60% with conventional methods (Claudius & Viby-Mogensen, 2008).

Fortier et al. (2015) performed the RECITE study to determine the severity of residual neuromuscular blockade with current practice. The study aimed to determine the number of patients entering the PACU with a TOF ratio of less than the recommended 0.9 to prevent respiratory events. The study took place at eight hospitals in Canada and included three hundred and eight participants. Rocuronium, a non-depolarizing neuromuscular blocking drug, was used and then was reversed with Neostigmine. The results showed a very high rate of residual NMB at 63% (95% CI) at extubation, and 56% (95% CI) at arrival to the PACU (Fortier et al., 2015). It

also determined that the incidence of residual paralysis did not differ among all different populations including gender, age, body mass index (BMI), or type of surgery. This study concluded that residual paralysis is common in all patients, and in all surgeries, and recommends changing current practice to using a more advanced monitoring system to detect residual paralysis.

In two randomized control trials, the evidence supported the use of an objective measure such as acceleromyography to determine a TOF ratio of >0.9. Murphy et al. (2011) determined that when using the objective measure, the group had a significantly lower incidence of residual blockade compared to the control group. In a similar study, the use of an objective monitor was associated with a lower incidence of a residual blockade of only 3% compared to the control group in which 16.7% of them entered the PACU with TOF ratio of <0.9 (Gatke, Viby-Mogensen, Rosenstock, Jensen, & Skovgaard, 2002)

TABLE 1. *Synthesis of evidence.*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
Cedborg et al. (2014). Pharyngeal function and breathing pattern during partial neuromuscular block in the elderly.	Evaluate the effects of NMB on individuals older than 65. Pharyngeal function, coordination of breathing and swallowing, and airway protection were assessed.	Non-randomized control. TOF ratio assessed at 0.7, 0.8, and 0.9	N=23 Study group: 17 Control Group: 6	Swallowing and pharyngeal dysfunction -Control 37% -Study 71% (P=0.005) No significant difference in control and study after TOF ratio of >0.9 (P=0.31) Coordination of breathing and swallowing No significant difference in control and study group (P=0.08) Mechanical properties and timing of pharyngeal swallowing and swallowing apnea No significant difference between control and study. Pharyngeal phase was shorter in men compared to women (P=0.013, ANOVA) Resting upper esophageal sphincter (UES) pressures Significantly decreased with partial block (TOF 0.70, $P < 0.001$; 0.80, $P < 0.001$; and >0.90, $P = 0.007$)	Increased pharyngeal dysfunction exists in those >65 years old when NMB exists. This leads to increased risk on aspiration and extended hospital stay. Resting esophageal sphincter tone is decreased with residual blockade

TABLE 1 – *Continued*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
Checketts et al., 2016. Recommendations for standards of monitoring during anesthesia and recovery 2015: Association of Anesthetists of Great Britain and Ireland	Recommendations for the standard of care for the Association of Anesthetists of Great Britain and Ireland	Guideline for standard of care Appendix 3: monitoring of neuromuscular blockade during induction, maintenance, and recovery of anesthesia	Updates and replaces 4th edition of standard of care		Recommendations -PNS mandatory when patients receive NMB drugs -TOF ratio of 0.9 most reliable for safe reversal -quantitative PNS is required to accurately assess TOF ratio.
Claudius & Viby-Mogensen, 2008. Acceleromyography for Use in Scientific and Clinical Practice	Evaluate current evidence and the relationship between using an acceleromyography monitor to access residual neuromuscular block (TOF ratio <0.9)	Systematic review.	Group 1: Use of acceleromyography for establishing dose-response relations. 3 Group 2: Acceleromyography compared with mechanomyography in pharmacodynamics studies. 13 Group 3: Acceleromyography compared with electromyography. 6 Group 4: Clinical studies comparing acceleromyography to signs, symptoms, and tests of residual paralysis. 16	Group 1: insufficient evidence due to the validity of studies. Group 2: Grade C evidence supporting use of the acceleromyography to access onset time and recovery using TOF ratio. Group 3: Grade C evidence supporting use of the acceleromyography interchangeably with electromyography to assess TOF ratio Group 4: Grade A evidence that acceleromyography is more sensitive to	There is strong evidence that supports perioperative monitoring with an objective monitor (acceleromyography) to detect residual paralysis. Acceleromyography is more sensitive than any of the usually applied tests including subjective or tactile evaluation.

TABLE 1 – *Continued*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
				assessing residual paralysis than usual applied tests (subjective). Also improves detection of residual paralysis.	
Debaene, Plaud, Dilly, & Donati, 2003. Residual Paralysis in the PACU after a Single Intubating Dose of Nondepolarizing Muscle Relaxant with an Intermediate Duration of Action.	Determine the amount of residual paralysis in the PACU after receiving a single dose of a non-depolarizing drug during intubation.	Over an 8-month period in one facility in France Prospective, open-labeled, nonrandomized, observational study	N=526 ASA I-III No reversal agent was given On arrival to the PACU, the TOF ratio was assessed using objective measures.	85 (16%) had a TOF of <0.7. 237 (45%) had a TOF of < 0.9. (P=0.01) When checked at two hours after drug TOF ratio of <0.9 was present in 37% When TOF ratio of <0.9 was achieved head lift test and tongue depressor test failed in 15% of patients.	The incidence of residual paralysis is clinically significant even two hours after the drug is given. Reversal should always be used when objective measures are not available.
Drobnik et al., 2010. A randomized simultaneous comparison of acceleromyography with a peripheral nerve stimulator for assessing reversal of Rocuronium-induced neuromuscular blockade with Sugammadex.	Determine the relationship between acceleromyography and PNS measuring reversal after Sugammadex	Assessor blinded, randomized, parallel group.	N=91 Randomized at 4 facilities. Acceleromyography was measured on one arm and PNS on the other. 30 were given 1mg -28 completed study 61 were given 4mg -61 completed	Scatter plot used to document times and then compared each group. Group given 1mg took significantly longer (2.3-148min, mean 17.2, SD 28.6, CI 95%) Group given 4mg (0.6-3.2min, mean 1.5 SD 0.7, CI 95%)	While Sugammadex substantially reduces the amount of time to reach a TOF ratio of 0.9, using an acceleromyography monitor is still needed to ensure adequate reversal.

TABLE 1 – *Continued*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
				PNS range in min (0.03-1.7, mean 0.8 SD 0.3, CI 95%) Acceleromyography range in min (0.6-3.2. mean 2.1 SD 1.7, CI 95%)	
Fortier et al., 2015 The RECITE Study: A Canadian Prospective, Multicenter Study of the Incidence and Severity of Residual Neuromuscular Blockade	To study and determine the incidence of residual NMB (TOF <0.9) just before extubation. 8 hospitals in Canada	Prospective observational study TOF ratios were obtained immediately at PACU using acceleromyography Anesthesia providers used subjective measures to assess TOF ratio before extubation.	IRB approved and consent was obtained. N=302 Mean age 48 70% female 54% ASA II	Incidence of residual blockade at extubation was 63.5% (95% CI) and 56.5% (95% CI) at arrival to PACU. Use of qualitative PNS was associated with a lower residual blockade on arrival in PACU. 51.1% vs 67.1%. (P=0.028) Each increase in TOF ratio of 0.1 was associated with 4% fewer bed visits in PACU (P=0.013)	Incidence of residual blockade (TOF<0.9) was 63.5% (95% CI) There is no difference in residual blockade between age or ASA class. Lower the TOF ratio the more likely to need supplemental oxygen.
Gatke, Viby-Mogensen, Rosenstock, Jensen, & Skovgaard, 2002. Postoperative muscle paralysis after Rocuronium: less	Determine if using an acceleromyography tool is more effective in assessing residual paralysis than not using a PNS.	Randomized control study	IRB approved. N=120 TOF group (n=60) Control group (n=60)	Study group: Residual paralysis (TOF <0.8) was found in 3% (P=0.029) Control Group:	Use of acceleromyography is associated with lower incidence of a residual blockade and increased time in recovery.

TABLE 1 – *Continued*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
residual block when acceleromyography is used.				Residual paralysis was found in 16.7% (P=0.029)	
Murphy et al., 2008. Intraoperative Acceleromyographic Monitoring Reduces the Risk of Residual Neuromuscular Blockade and Adverse Respiratory Events in the Post Anesthesia Care Unit.	Compare the use of objective monitoring and subjective monitoring when assessing for residual NMB.	Randomized control study N=185 Group 1: Monitored using acceleromyography Group 2: Monitored using conventional subjective measures.	Patients undergoing surgery that need to have NMB drugs during the procedure. The study was IRB approved and consent was obtained.	Conventional TOF group arriving to PACU With residual blockade <0.9TOF 30% (P=0.0001) 13% arriving in the PACU with severe blockade of <0.7 TOF ratio (P=0.001) Median SpO2 value 95% arriving in PACU (P=0.0001) Acceleromyography group 4.5% arriving to PACU with <0.9 TOF ratio (P=0.0001) 0% arriving to PACU with TOF <0.7 (P=0.001) Median SpO2 value arriving to PACU 97% (P=0.0001) Severe hypoxia was seen in 21.1% of control group and 0% of the study group (P=0.0001)	There is a significant difference in the two groups and TOF ratio. The acceleromyography group had a significantly lower number of residual paralysis than the subjective group. Acceleromyography can significantly reduce the risk of adverse respiratory events.

TABLE 1 – *Continued*

Author/ Year	Purpose	Design	Sample	Data Collection/Results	Findings
Murphy et al., 2011. Intraoperative Acceleromyography Monitoring Reduces Symptoms of Muscle Weakness and Improves Quality of Recovery in the Early Postoperative Period	Determine if using an acceleromyography monitor during the perioperative period will reduce symptoms of muscle weakness and improve the quality of recovery compared to the use of a subjective tool.	Randomized control study Single hospital in Chicago	IRB approved N= 155 Acceleromyography group monitored during perioperative phase. 76 Control group monitored during perioperative phase with subjective measures. 74	TOF ratio on admission to PACU was significantly higher in the acceleromyography group (0.98) than in the control group (0.88) (P=0.004) Patients with TOF <0.9 was 14.5% vs. 50% (P=0.0001) Patients with TOF <0.7 was 4% vs 18.9% (P=0.0004) The linear model revealed study group had less overall weakness and fewer symptoms including muscle weakness across all points measured (P=0.0001) Median rating was 4 in the study group compared to 6 in control group using 1-10 scale	Patients in the acceleromyography group had a lower incidence of TOF ratio <0.9 entering the PACU Patients also exhibited fewer signs of muscle weakness.
Sauer, Stahn, Soltesz, Noeldge-Schomburg, & Mencke, 2011. The influence of residual neuromuscular block on the incidence of critical respiratory events. A randomized, prospective, placebo-controlled trial.	Determine the correlation between residual NMB and critical respiratory events	Randomized placebo-controlled clinical trial	N=114 Group 1: patients given neostigmine (20mcg/kg) Group 2: placebo group.	Group 1: 16 patients became hypoxic in PACU (SaO2<93%) All patients were extubated with a TOF ratio >0.9 (P=0.021) Group 2 29 patients became hypoxic in PACU. (P=0.021) Median TOF ratio on extubation was 0.7. (P=0.0001)	Even minimal residual blockade is associated with critical respiratory events including hypoxemia in the PACU.

Other studies included the effects of even a minimal amount of residual block and the resulting associated complications. The highest risk determined is that the patients become hypoxic due to inability to protect their airway. The authors found that in the hypoxic group, 45% of them had a TOF ratio of <0.9 (Sauer, Stahn, Soltesz, Noeldge-Schomburg, & Mencke, 2011). Studies also showed the incidence of residual blockade based on the timing of the NMB drug and how long the effects can last. The study concluded that when the residual blockade was checked two hours after giving a NMB drug, 37% of the patients still had a TOF ratio of <0.9 determining that a reversal agent should always be used after given a NMB drug (Debaene, Plaud, Dilly, & Donati, 2003).

After completing a thorough literature review examining the current practice and consequences of residual blockade, the current evidence overwhelmingly supports the need to update practice and include the use of objective tools after a patient is given a NMB drug. While a few of the studies are older than ten years, these are still relevant in current practice. Many of these studies are being used to develop similar clinical practice guidelines within the anesthesia community. The research presented provides insight into the problem of residual neuromuscular blockade, along with identifying the lack of consistent practice and the negative outcomes associated with an inadequate reversal. Highlighting the significant gap between the research and practice, in February of 2018, the Anesthesia Patient Safety Foundation created a collaborative panel on neuromuscular blockade and patient safety and presented recommendations from the panel. These recommendations include quantitative monitoring when NMB drugs are used, peripheral nerve stimulators should be mandatory, clinical signs should not be used to assess

adequate recovery, and organizations need to develop standards and guidelines (Murphy G., 2018).

METHODS

Design

This project aimed to change current practice using Lewin's change theory by unfreezing the current practice of not using a CPG to prevent the complication of a residual neuromuscular blockade. The next step was to change the management of neuromuscular blockade by developing a CPG with stakeholders input for use at the local level. Lastly, the goal was to re-freeze the new practice by creating a CPG for implementation at this facility as standard practice (Sutherland, Applying Lewin's Change Management Theory to the Implementation of Bar-Coded Medication Administration, 2013). The project used elements of the knowledge to action framework to translate the current research into a CPG at this local facility (Graham I. D. et al., 2006). After the CPG was completed it was evaluated by anesthesia providers trained to use the AGREE II tool to assess quality (Brouwers et al., 2010). After the CPG was determined to be valid, the CPG was presented to the local anesthesia department.

Setting

This project took place within an anesthesia practice group contracted to provide services at a medical facility in the Phoenix-Metropolitan area.

Participants

Convenience sampling was used to obtain volunteer anesthesia providers, including one provider working at the local healthcare organization. The information gathered during the interview was used to determine the need for the CPG and how it can be used to affect change in

their practice. Four expert anesthesia providers were included in the My AGREE PLUS evaluation process. The CPG was tailored for the anesthesia group practicing at Mountain Vista Medical Center in Mesa, Arizona.

AGREE II

Introduction

The Appraisal of Guidelines for Research & Evaluation (AGREE) instrument was originally published in 2003 as a method to determine the quality of clinical practice guidelines. The collaboration defined the quality of the guidelines as "the confidence that the potential biases of guideline development have been addressed adequately and that the recommendations are both internally and externally valid, and are feasible for practice." (Brouwers et al., 2010) The original AGREE instrument was made up of 23 items which assessed 6 quality domains in the newly developed guideline. To refine the instrument, it improved the measurement properties to increase the reliability and validity and created a user's manual. With this update, the developers updated the name to AGREE II (Brouwers et al., 2010).

The AGREE II instrument is intended to be used by health care providers who have developed a guideline to be assessed before adopting the guideline in their current practice. It is designed to be applicable at a local level, regional level, or national level. When the tool was updated it also included resources such as the AGREE Research Trust which has free downloads, online training, references, and information about AGREE projects (Brouwers et al., 2010). Before beginning the appraisal process it is recommended that the user read the user's manual in full. The user's manual also states that the guideline should be appraised by a minimum of 2 appraisers and preferably 4. This project utilized four evaluators from the anesthesia department.

The structure of the AGREE II evaluation includes 23 key items that are part of 6 domains (See Appendix A). At the end of the assessment, there are 2 global rating items that rate the overall guideline. The items are rated on a 7-point scale; 1 strongly disagrees and 7 strongly agrees. A quality score for each domain was calculated to determine a recommendation for use of the guideline.

Domain 1. Scope and Purpose

The objective of this domain is to determine if the guideline objectives are described in detail and are specifically related to a clinical problem associated with the specified population. Part 2 of this domain covers the question being answered by the guideline including the target population, interventions, healthcare setting, and outcomes (Brouwers et al., 2010). Part 3 specifically addresses the population in which the guideline will be applied which may include the clinical description; operative patients in this study.

Domain 2. Stakeholder Involvement

This domain begins by determining if the developer(s) are relevant to the issue and involved in the development process. This may be research members or members involved in final recommendations. Part 2 of this domain assesses if the target population have been sought out and involved in the process through consultation or external review. Part 3 determines if the target users have clearly been defined.

Domain 3. Rigor of Development

The focus on the search and synthesis of the evidence is part of this domain. Terms used, sources, and the dates of the literature should be listed and relevant. The search strategy should be comprehensive and performed in a way to reduce potential bias. The criteria for selecting the

evidence should be listed and details of any excluded research should be clearly stated. There also needs to be explanations describing the methods used to develop the guideline and include the potential benefits, side effects, and risks that have been considered. The link between the research and the recommendations need to be clear and the guideline should be reviewed by experts that are not part of the development process. Finally, there should be a clear timeline and procedure for updating the guideline to include new evidence.

Domain 4. Clarity of Presentation

This domain ensures that the recommendation is presented in a manner that is precise and described the recommendations for the given population. It should also provide and compare the different options that are available in current practice**.** The last part of this domain ensures that the key recommendations are easily found in the guideline and they answer the main question.

Domain 5. Applicability

For the guideline to be effective it must be applicable to the populations targeted. This domain will ensure that facilitators and barriers have been considered and options to overcome these barriers are provided. Recommendations and tools are also provided to assist in the implementation such as an educational presentation. Cost and resources are discussed and potential impact of implementing the guideline is considered. Finally, this domain presents measuring recommendations to ensure the guideline is effective after implementation.

Domain 6. Editorial Independence

If there is any external funding or contributions, they must be clearly listed in a statement that explained the results have not been influenced by the external funding. If there are any competing interest within the developing body they must also be listed.

Overall Guideline Assessment

The first question asked was to rate the overall quality of the guideline; which also uses the 7-point scale. The last question asked of the evaluator is if they would recommend this guideline for use in their current practice; the answers provided are yes, yes with modifications, and no.

AGREE II PLUS

The Agree Trust recommends that at least two experts evaluate the guideline, however, it is recommended there be four. When the experts are selected, they are informed to visit the agreetrust.org website where online training tools are made available in the form of tutorials and user guides. The tutorials consist of one overview tutorial that takes approximately ten minutes to complete and a second practice exercise tutorial that takes approximately one hour to complete (Agree Trust, 2018). After consent is given by the appraisers, the coordinator will send an invitation to the My AGREE PLUS online platform where the appraisers will gain access to the guideline and the evaluation tool. The coordinator will then be able to track the progress and results of the appraisal. Results will then be made available for this project and available to the appraisers.

Intervention

One anesthesia provider within the group was consulted to work with the author in developing the CPG. This consultant provided valuable information about current practice within the group, current equipment that is available to the group, and barriers to application of the CPG. Using current evidenced-based recommendations and local insight from the consultant, the author developed the CPG for the anesthesia group. The consultant then provided edits to the

CPG that would make it easier to implement at this facility. When the consultant and the author completed the CPG, it was then sent to the appraisers for evaluation. After the CPG was deemed valid for this local anesthesia group, it was presented and reviewed by the local anesthesia department stakeholders. The CPG was then made available to the department to adopt as the standard of care. (See appendix F)

Tools

The anesthesia providers completed online training on the use of the AGREE II instrument being used to evaluate the quality of the newly developed CPG. The providers appraised the CPG using the My AGREE PLUS on-line platform through an email invitation to access and evaluate the CPG.

Data Analysis

The My AGREE PLUS online platform provided the project investigators with results to the quality of the CPG. Four appraisers were identified via email to complete the appraisal process. The appraisers received a PDF copy of the CPG and instructions on how to complete the training modules and evaluation. The appraisers then answered the questions in each domain. Each question that the appraisers answered was rated on a 7- point scale; 1 being strongly disagree and 7 being strongly agree. The final scores are then calculated and given a percentage value based on each of the six domains. The final question stated if the appraiser would recommend the CPG or not. A domain score of 70% or greater was determined to be a high-quality CPG (Brouwers et al., 2010).

Resources

There was not any funding necessary for this project. There was a requirement for the participants' time to use the AGREE II tool and participation in the learning and evaluation using the AGREE II.

Ethical Considerations

Respect for Persons

This project included anesthesia providers only and not patients. Any contributions made were listed and consent was obtained for information and use of the evaluation tool.

Beneficence

There was no direct contact between this project and direct patient care. There was no direct risk to patients. The CPG will act as a guide to anesthesia providers to establish the safest standard of care for delivery to the patient. Institutional Review Board approval was obtained prior to implementation to ensure all parties are protected.

Justice

This projects target population were anesthesia providers using neuromuscular blockers and reversals. There were no exclusion criteria to gain access to the CPG. The newly designed CPG was made available to providers to adopt as a standard of care. The CPG provided the most up to date information about caring for patients receiving NMB drugs to reduce residual paralysis.

RESULTS

To ensure a high-quality CPG has been created using the AGREE II instrument, it needs to be evaluated by 2-4 appraisers who have been trained to use the My AGREE PLUS platform

(Brouwers et al., 2010). After consulting with an expert anesthesia provider, the CPG was developed for the anesthesia group. Four appraisers were then identified via email and asked to complete the appraisal of the CPG. The four appraisers received a PDF copy of the CPG (Appendix F) with instructions on how to complete the appraisal. This included instructions on how to create an account on My AGREE PLUS and how to complete the AGREE II Overview Tutorial and practice exercises to ensure complete understanding on the tool which will ensure a high-quality CPG is established (Brouwers et al., 2010). The author of the CPG titled "Clinical Practice Guideline for Monitoring Neuromuscular Blockade" sent invites to the appraisers via the My AGREE PLUS tool and was established as the coordinator of the group. The appraisers were given one month's time to complete the appraisals, which were all completed by March 1, 2019. Upon completion, the coordinator was emailed notification that the results were available.

The AGREE II instrument provided in Appendix A provides the questions answered by the appraisers in each domain. The appraisers answered the questions using a one to seven scale and then had the option to add additional comments below. The domains are scored individually and then a final overall assessment is provided (Brouwers et al., 2010). The final question asked if the appraisers would recommend the CPG (Brouwers et al., 2010). The results of the evaluation are provided in Appendix D followed by the results comments in Appendix E.

Each domain received a final percentage score based on the appraisers' evaluations. Scores for all appraisers were added for each question (see Table 2) and displayed as a total. Below the totals for each question are the total for the domain which was then converted into a percentage score for each domain. The scores for each domain were 96% for domain 1, 92% for domain 2, 95% for domain 3, 94% for domain 4, 94% for domain 5, and 98% for domain 6.

According to Brouwers et al, a domain score above 70% represents a high-quality domain (see Appendix C for scoring AGREE II). The appraisers then provided the CPG with an overall assessment score of 100%. In the final question asking if the appraisers would recommend this guideline for clinical use, the appraisers all stated “yes” with no modifications.

TABLE 2. *AGREE II score calculator.*

Seven-point AGREE II Score Calculator

You must fill in ALL of the Question ratings from an appraiser for the Domain score to be accurate.

**Note: Please use the AGREE II User's Manual for full instructions.*

Total # of Appraisers	Appraiser				
4	*1*	*2*	*3*	*4*	
Domain 1 - Scope and Purpose					
Q1 - The overall objective(s) of the guideline is (are) specifically described.	7	7	6	7	27
Q2 - The health question(s) covered by the guideline is (are) specifically described.	7	7	7	7	28
Q3 - The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.	7	6	6	7	26
	21	20	19	21	**81**
			Domain 1 Score for 4 Appraiser(s):		96%
Domain 2 - Stakeholder Involvement					
Q4 - The guideline development group includes individuals from all relevant professional groups.	7	6	7	5	25
Q5 - The views and preferences of the target population (patients, public, etc.) have been sought.	7	6	7	6	26
Q6 - The target users of the guideline are clearly defined.	7	7	6	7	27
	21	19	20	18	**78**
			Domain 2 Score for 4 Appraiser(s):		92%
Domain 3 - Rigour of Development					
Q7 - Systematic methods were used to search for evidence.	7	7	7	7	28
Q8 - The criteria for selecting the evidence are clearly described.	7	7	7	7	28
Q9 - The strengths and limitations of the body of evidence are clearly described.	7	7	6	6	26
Q10 - The methods for formulating the recommendations are clearly described.	6	6	6	7	25
Q11 - The health benefits, side efects, and risks have been considered in formulating the recommendations.	7	7	7	7	28
Q12 - There is an explicit link between the recommendations and the supporting evidence.	7	7	7	7	28
Q13 - The guideline has been externally reviewed by experts prior to its publication.	7	6	7	6	26
Q14 - A procedure for updating the guideline is provided.	6	6	7	6	25
	54	53	54	53	**214**
			Domain 3 Score for 4 Appraiser(s):		95%

TABLE 2 – *Continued*

Domain 4 - Clarity of Presentation					
Q15 - The recommendations are specific and unambiguous.	7	6	6	7	26
Q16 - The different options for management of the condition or health issue are clearly presented.	7	6	6	7	26
Q17 - Key recommendations are easily identifiable	7	7	7	7	28
	21	19	19	21	**80**
			Domain 4 Score for 4 Appraiser(s):		94%
Domain 5 - Applicability					
Q18 - The guideline describes facilitators and barriers to its application.	7	7	6	7	27
Q19 - The guideline provides advice and/or tools on how the recommendations can be put into practice.	6	7	7	6	26
Q20 - The potential resource implications of applying the recommendations have been considered.	7	7	6	6	26
Q21 - The guideline presents monitoring and/or auditing criteria.	7	7	7	6	27
	27	28	26	25	**106**
			Domain 5 Score for 4 Appraiser(s):		94%
Domain 6 - Editorial Independence					
Q22 - The views of the funding body have not influenced the content of the guideline.	7	7	7	7	28
Q23 - Competing interests of guideline development group members have been recorded and addressed.	7	7	6	7	27
	14	14	13	14	**55**
			Domain 6 Score for 4 Appraiser(s):		98%
Overall Guideline Assessment					
1. Rate the overall quality of this guideline. *Scoring: 1(Least Quality) - 7(Highest Quality)*	7	7	7	7	
2. I would recommend this guideline for use. *Scoring: "Yes", "Yes, with modifications", "No"*	Yes	Yes	Yes	Yes	

Each domain allows the appraiser the option to include comments on the questions regarding the CPG. The comments are designed to help clarify the domain and provide additional feedback to the coordinator of the CPG (Appendix E). While there were no comments on the domains of the CPG, appraiser 1 provided valuable feedback about a barrier to implementing the CPG stating, “the potential barrier that I can see to implementing this CPG will

be the cost of purchasing the new nerve stimulators since the facility does not currently have them. Perhaps including a cost analysis on the different monitors so they could be replaced with the objective monitors in the future."

Strengths and Weaknesses

The CPG was developed at a local level to directly impact practice within the anesthesia group. The CPG included current literature from level one evidence that supports the key recommendation in the CPG. In the past, objective monitoring devises have been expensive and cumbersome to have in every anesthesia setting that uses neuromuscular blockers. Technological advances have made the equipment much more portable and affordable. By using the AGREE II appraisal tool, the author ensured that a high-quality CPG was developed and that the appraisers were trained to use the tool. By involving the stakeholders in the development process, they are more likely to implement this CPG into practice.

One limitation identified by appraiser 1 was the potential for increased cost. Currently operating rooms have subjective nerve stimulators that can be used. New, objective monitors would need to be purchased to use objective TOF monitoring. This would be an initial cost to the provider or facility. While in the past this equipment was much more expensive than the subjective tools, it has come down to a reasonable expense when considering patient safety. It is recommended that as the subjective monitors need to be replaced that objective monitors take their place. This limitation is addressed in the CPG by stating that when objective measures are not available, the use of subjective measures should be mandatory.

DISCUSSION

The clinical practice guideline included three key recommendations; a train of four ratio of 0.9 or greater should be used as the gold standard to determine if adequate recovery has taken place, quantitative monitoring should be available whenever a neuromuscular blocking drug is administered as it is more accurate at determining a TOF ratio of 0.9 or greater. If unavailable, the use of a subjective peripheral nerve stimulator is mandatory, and clinical signs such as 5-second head lift or adequate tidal volume do not guarantee adequate reversal and should not be used alone to determine level of blockade. Based on the AGREE II evaluation performed by the appraisers, the CPG performed well above the 70% threshold in all domains confirming this is a high-quality CPG ready for implementation (Brouwers et al., 2010). All domain scored in the 90% with the final assessment being a score of 100% that the appraisers would recommend this CPG for implementation. If implemented, this CPG could reduce respiratory complications associated with residual neuromuscular blockade in the patients receiving these drugs (Brull et al., 2008). Appraiser 1 identified a cost concern with purchasing new equipment. While in the past objective monitoring has been much more expensive, newer equipment has provided better accuracy with reasonable costs to the provider (Checketts M. et al., 2015).

Conclusion

The ability of the anesthesia provider to use neuromuscular blocking medications to assist in the safety of surgical procedures continues to be adapted. With recent literature stating that a train of four ratio of 0.9 should be the gold standard of monitoring, it's important to accurately be able to identify when accurate reversal has taken place. After an extensive literature review, the research clearly supports the key recommendations used in the CPG. Using Lewin's Change

Theory and the Knowledge to Action Framework as the theoretical framework assisted the author in translating the current evidence to create a CPG with the assistance of a clinical expert. After the development of the CPG, the author used the AGREE II appraisal tool to ensure a high-quality guideline had been developed. Four anesthesia providers appraised the CPG giving it overwhelmingly positive results in the 90% and above range which is much higher than the 70% needed to insure a high-quality CPG (Brouwers et al., 2010). All providers stated that they would recommend the use of the CPG within their anesthesia group. At conclusion of the appraisal process the results are to be disseminated at an anesthesia convention where a poster presentation will be conducted. As technology becomes more affordable and advanced, the implementation of this CPG will become more advantageous to the stakeholders and the barriers will be reduced.

DNP Essentials

To complete this project, the University of Arizona DNP essentials needed to be achieved. DNP essential I, application of scientific underpinnings to practice, was met by the inclusion of Lewin's Change Theory and the Knowledge to Action Framework that was used as the theoretical framework for completing this project. DNP essential II, application of organizational and systems leadership for quality improvement and systems thinking, was met by establishing an expert provider to assist in the development in the CPG followed by key stakeholders that appraised the CPG. DNP essential III, application of clinical scholarship and analytical methods for evidenced-based practice, was met by using current evidenced-based research to develop a clinical practice guideline. DNP essential IV, application of information systems/technology and patient care technology for the improvement and transformation of health care, was met by creating a CPG recommending the use of an objective NMB monitor that

can display a quantitative number that can be entered and tracked in the electronic health record. DNP essential V, application of healthcare policy for advocacy in health care, was met by creating a CPG which will improve patient outcomes by decreasing residual paralysis. DNP essential VI, application of inter-professional collaboration for improving patient and population health outcomes, was met by engaging the stakeholders who provide anesthesia to develop and create a CPG which will improve outcomes. DNP essential VII, application of clinical prevention and population health for improving the Nation's health, was met by improving the anesthesia care and preventing postoperative respiratory complications. DNP essential VIII, application of advanced practice competencies, was met throughout the project by incorporating knowledge of anesthesia principles, research principles, and application of evidenced-based practice to develop a CPG which can be adopted at a local level to improve patient outcomes.

APPENDIX A:

AGREE II INSTRUMENT

DOMAIN 1. SCOPE AND PURPOSE

1. The overall objective(s) of the guideline is (are) specifically described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

2. The health question(s) covered by the guideline is (are) specifically described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 2. STAKEHOLDER INVOLVEMENT

4. The guideline development group includes individuals from all relevant professional groups.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

5. The views and preferences of the target population (patients, public, etc.) have been sought.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

6. The target users of the guideline are clearly defined.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 3. RIGOUR OF DEVELOPMENT

7. Systematic methods were used to search for evidence.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

8. The criteria for selecting the evidence are clearly described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

9. The strengths and limitations of the body of evidence are clearly described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 3. RIGOUR OF DEVELOPMENT continued

10. The methods for formulating the recommendations are clearly described.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

11. The health benefits, side effects, and risks have been considered in formulating the recommendations.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

12. There is an explicit link between the recommendations and the supporting evidence.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 3. RIGOUR OF DEVELOPMENT continued

13. The guideline has been externally reviewed by experts prior to its publication.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

14. A procedure for updating the guideline is provided.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 4. CLARITY OF PRESENTATION

15. The recommendations are specific and unambiguous.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

16. The different options for management of the condition or health issue are clearly presented.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

17. Key recommendations are easily identifiable.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 5. APPLICABILITY

18. The guideline describes facilitators and barriers to its application.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

19. The guideline provides advice and/or tools on how the recommendations can be put into practice.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

20. The potential resource implications of applying the recommendations have been considered.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 5. APPLICABILITY continued

21. The guideline presents monitoring and/or auditing criteria.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

DOMAIN 6. EDITORIAL INDEPENDENCE

22. The views of the funding body have not influenced the content of the guideline.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

23. Competing interests of guideline development group members have been recorded and addressed.

1 Strongly Disagree	2	3	4	5	6	7 Strongly Agree

Comments

OVERALL GUIDELINE ASSESSMENT

For each question, please choose the response which best characterizes the guideline assessed:

1. Rate the overall quality of this guideline.

1 Lowest possible quality	2	3	4	5	6	7 Highest possible quality

2. I would recommend this guideline for use.

Yes	
Yes, with modifications	
No	

NOTES

(Brouwers et al., 2010)

APPENDIX B:

SITE APPROVAL LETTER

Anesthesia Physicians of Arizona
1301 South Crismon Road
Mesa, AZ 85209

January 1, 2019

University of Arizona Institutional Review Board
c/o Office of Human Subjects
1618 E. Helen St
Tucson, AZ 85721

Please note that Mr. Austin Thruston, UA Doctor of Nursing Practice student, has permission of Anesthesia Physicians of Arizona to conduct an evidenced-based project for his project, "Development of a Clinical Practice Guideline for Monitoring Neuromuscular Blockade."

Mr. Thruston will develop a clinical practice guideline with the input of a CRNA from our anesthesia group. The CRNA will provide expert opinion and valuable organizational insight from Mountain Vista Medical Center. This will include an interview conducted of site as agreed upon from both parties. Mr. Thruston's activities will be completed by April 1, 2019.

Mr. Thruston has agreed to provide the developed clinical practice guideline and evaluation results upon completion. He has further agreed to present the results to the providers as per organizational determination.

If there are any questions, please contact my office.

Signed,

Dr. Ned Sciortino, D.O.
Medical Director of Anesthesia
Director of Medical Education

APPENDIX C:

SCORING THE AGREE II

IV. Scoring the AGREE II

A quality score is calculated for each of the six AGREE II domains. The six domain scores are independent and should not be aggregated into a single quality score.

i) Calculating Domain Scores

Domain scores are calculated by summing up all the scores of the individual items in a domain and by scaling the total as a percentage of the maximum possible score for that domain.

Example:

If 4 appraisers give the following scores for Domain 1 (Scope & Purpose):

	Item 1	Item 2	Item 3	**Total**
Appraiser 1	5	6	6	**17**
Appraiser 2	6	6	7	**19**
Appraiser 3	2	4	3	**9**
Appraiser 4	3	3	2	**8**
Total	**16**	**19**	**18**	**53**

Maximum possible score = 7 (strongly agree) x 3 (items) x 4 (appraisers) = 84
Minimum possible score = 1 (strongly disagree) x 3 (items) x 4 (appraisers) = 12

The scaled domain score will be:

$$\frac{\text{Obtained score} - \text{Minimum possible score}}{\text{Maximum possible score} - \text{Minimum possible score}}$$

$$\frac{53 - 12}{84 - 12} \times 100 = \frac{41}{72} \times 100 = 0.5694 \times 100 = 57\ \%$$

If items are not included, appropriate modifications to the calculations of maximum and minimum possible scores are required.

ii) Interpreting Domain Scores

Domain scores can be used to identify strengths and limitations of guidelines, to compare methodological quality between guidelines, or to select high quality guidelines for adaptation, endorsement, or implementation. At present, there are no empirical data to link specific quality scores with specific implementation outcomes (e.g., speed of adoption, spread of adoption) or specific clinical outcomes; this makes selection of quality thresholds to differentiate between high, moderate, and low quality guidelines a challenge. In the absence of these data, we provide examples of approaches that can be used to set quality thresholds:

- Prioritizing one domain: Through consensus or based on decisions by leadership, one quality domain may be prioritized over the others. Thus, thresholds can be created based on scores for the prioritized domain (e.g., high quality guidelines are those with a Domain 3 score >70%).
- Staged AGREE II appraisal: If users value one domain over the others, they can first appraise the guidelines using that domain only. Only those guidelines that meet a quality threshold for that domain (e.g., >70%) are then appraised using the other five AGREE II domains.
- Considering all domain scores: Users can create a threshold across all six domain scores based on consensus or decisions by leadership (e.g., high quality guidelines are those with domain scores that are all >70%). Alternatively, users might create different thresholds for each of the domains.
- Thresholds for improvement over time: If evaluating changes in scores for guidelines over time, users can create thresholds for improvement (e.g., at least 10% improvement in each domain score for guidelines by a particular developer over a period of five years).

Any decisions about how to define quality thresholds should be made by a panel of all relevant stakeholders before beginning the AGREE II appraisals. Decisions should be guided by the context in which the guideline is to be used and by evaluating the importance of the different domains and items in that context.

APPENDIX D:

AGREE II RATINGS

A critical group appraisal of: Clinical Practice Guideline for Monitoring Neuromuscular Blockade using the AGREE II Instrument

Created with the AGREE II Online Guideline Appraisal Tool.

No endorsement of the content of this document by the AGREE Research Trust should be implied.

Co-ordinator: Austin Thruston

Date: 1 March 2019

Email: austinthruston@email.arizona.edu

URL of this appraisal: http://www.agreetrust.org/group-appraisal/10173

Guideline URL:

Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Domain 6	OA 1	OA 2
96%	92%	95%	94%	94%	98%	100%	Yes - 4, Yes with modifications - 0, No - 0

Domain 1. Scope and Purpose				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
Item 1	7	7	6	7
Item 2	7	7	7	7
Item 3	7	6	6	7
Domain 2. Stakeholder Involvement				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
Item 4	7	6	7	5
Item 5	7	6	7	6
Item 6	7	7	6	7
Domain 3. Rigour of Development				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
Item 7	7	7	7	7
Item 8	7	7	7	7
Item 9	7	7	6	6
Item 10	6	6	6	7
Item 11	7	7	7	7
Item 12	7	7	7	7
Item 13	7	6	7	6
Item 14	6	6	7	6
Domain 4. Clarity of Presentation				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
Item 15	7	6	6	7
Item 16	7	6	6	7
Item 17	7	7	7	7
Domain 5. Applicability				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1

Item 18	7	7	6	7
Item 19	6	7	7	6
Item 20	7	7	6	6
Item 21	7	7	7	6
Domain 6. Editorial Independence				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
Item 22	7	7	7	7
Item 23	7	7	6	7
Overall Assessment				
	Appraiser 2	Appraiser 4	Appraiser 5	Appraiser 1
OA1	7	7	7	7

Created online at www.agreetrust.org 1 March 2019

APPENDIX E:

AGREE II COMMENTS

A critical group appraisal of: Clinical Practice Guideline for Monitoring Neuromuscular Blockade using the AGREE II Instrument

Created with the AGREE II Online Guideline Appraisal Tool.

No endorsement of the content of this document by the AGREE Research Trust should be implied.

Co-ordinator: Austin Thruston

Email: austinthruston@email.arizona.edu

Date: 1 March 2019

URL of this appraisal: http://www.agreetrust.org/group-appraisal/10173

Guideline URL:

Comments

Domain 1. Scope and Purpose

No comments found for this domain.

Domain 2. Stakeholder Involvement

No comments found for this domain.

Domain 3. Rigour of Development

No comments found for this domain.

Domain 4. Clarity of Presentation

No comments found for this domain.

Domain 5. Applicability

No comments found for this domain.

Domain 6. Editorial Independence

No comments found for this domain.

Overall Assessment

- Appraiser 1: The potential barrier that I can see to implementing this CPG will be the cost of purchasing the new nerve stimulators since the facility does not currently have them. Perhaps including a cost analysis on the different monitors so they could be replaced with the objective monitors in the future.

APPENDIX F:

CLINICAL PRACTICE GUIDELINE

February 11, 2019

Guideline Title

Clinical Practice Guideline for Monitoring Neuromuscular Blockade

Guideline Objectives:

This guideline provides certified registered nurse anesthetists (CRNA), physician anesthesiologists (MDA), and anesthesiologist assistants (AA) evidenced based guidelines for monitoring neuromuscular blockade after a non-depolarizing neuromuscular blocking drug is administered. The goal is to reduce residual paralysis in the post anesthesia care unit (PACU), decrease respiratory complications, and increase patient safety. This guideline provides evidence-based recommendations for using the proper equipment to monitor residual paralysis, what should be used as the gold standard to assess adequate recovery, and what methods have been proven to be inaccurate in determining adequate reversal.

Questions:

What is the most accurate way to determine if adequate reversal has taken place? What is the most accurate way to measure neuromuscular blockade and adequate reversal? Are current subjective measures accurate at determining adequate reversal?

Target Population:

This guideline is intended for all surgical populations that are given a neuromuscular blocking drug intraoperatively to assist with surgical relaxation. This includes those given non-depolarizing and depolarizing neuromuscular blocking drugs. Surgical patients excluded from this guideline include those not given a neuromuscular blocking drug.

Clinical Specialty:

Anesthesia

Intended Users:

Certified Registered Nurse Anesthetists

Physician Anesthesiologist

Anesthesiologist Assistants

Key Recommendations:

1. A train of four (TOF) ratio of 0.9 or greater should be used as the gold standard to determine if adequate recovery has taken place [2,6,10].

Grade of Evidence	Grade A
Risks, Harm, Costs	No risk or harm. Possible cost for new equipment if facility is not currently using peripheral nerve stimulators. Additional training for use of objective peripheral nerve stimulators.
Benefit	Adequate return of neuromuscular function for extubation and airway protection. Reduction in residual paralysis and adverse respiratory events. Decrease in costs associated with adverse respiratory events.
Exclusion	Patients not receiving neuromuscular blocking drug
Level of evidence	Level I
Strength descriptor	Strong recommendation

2. Quantitative monitoring should be available whenever a neuromuscular blocking drug is administered as it is more accurate at determining a TOF ratio of 0.9 or greater. If unavailable, the use of a subjective peripheral nerve stimulator is mandatory [2,3,5,7,8,9].

Grade of Evidence	Grade A
Risks, Harm, Costs	No risk or harm. Possible cost for new equipment if facility is not currently using objective peripheral nerve stimulators. Additional training for use of objective peripheral nerve stimulators.
Benefit	Adequate return of neuromuscular function for extubation and airway protection. Reduction in residual paralysis and adverse respiratory events. Decrease in costs associated with adverse respiratory events. Accurate determination of neuromuscular function.
Exclusion	Patients not receiving neuromuscular blocking drug
Level of evidence	Level I
Strength descriptor	Strong recommendation

3. Clinical signs such as 5-second head lift or adequate tidal volume do not guarantee adequate reversal and should not be used alone to determine level of blockade [1,2,4,10].

Grade of Evidence	Grade A
Risks, Harm, Costs	No risk or harm.
Benefit	Adequate return of neuromuscular function for extubation and airway protection. Reduction in residual paralysis and adverse respiratory events. Decrease in costs associated with adverse respiratory events. Standardize monitoring of neuromuscular function
Exclusion	Patients not receiving neuromuscular blocking drug
Level of evidence	Level I
Strength descriptor	Strong recommendation

Supporting Evidence:

High quality evidence supports the use of quality measures to accurately determine the depth of neuromuscular blockade. Literature supports the use of an objective monitoring devise to accurately determine the TOF ratio. The TOF ratio should be the gold standard in determining if adequate reversal has taken place. Furthermore, subjective measures to determine full recovery from a neuromuscular blocking drug is unreliable and should not be used alone to determine depth of block.

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Search Methods:

An extensive literature review was completed to find the best evidence to support the need for change. There were three primary literature searches; including PubMed, Cumulative Index of Nursing and Allied Health Literature (CINAHL), and the Cochrane Library. The primary keywords used were peripheral nerve stimulation and residual neuromuscular block. Other related terms included objective monitoring, neuromuscular junction, anesthesia, and subjective monitoring. Inclusion criteria for the literature review included studies published within the last ten years, human subjects, English language, and full-text availability.

Strength of Evidence:

The following figures were utilized to determine the strength of the evidence and the grade of recommendation:

Level of Evidence	Description
Level I	Evidence from a systematic review or meta-analysis of all relevant RCTs (randomized controlled trial) or evidence-based clinical practice guidelines based on systematic reviews of RCTs or three or more RCTs of good quality that have similar results
Level II	Evidence obtained from at least one well-designed RCT (e.g. large multi-site RCT).
Level III	Evidence obtained from well-designed controlled trials without randomization

	(i.e. quasi-experimental).
Level IV	Evidence from well-designed case-control or cohort studies.
Level V	Evidence from systematic reviews of descriptive and qualitative studies (meta-synthesis).
Level VI	Evidence from a single descriptive or qualitative study.
Level VII	Evidence from the opinion of authorities and/or reports of expert committees.

Ackley, B. J., Swan, B. A., Ladwig, G., & Tucker, S. (2008). *Evidence-based nursing care guidelines: Medical-surgical interventions.* (p. 7). St. Louis, MO: Mosby Elsevier.

Grade	Descriptor	Qualifying Evidence	Implications for Practice
A	Strong Recommendation	Level I evidence or consistent findings from multiple studies of levels II, III, or IV	Clinicians should follow strong recommendations unless clear or compelling rationale for an alternative approach is present.
B	Recommendation	Levels II, III, or IV evidence and findings are generally consistent	Generally, clinicians should follow a recommendation but should remain alert to new information and sensitive to patient preferences
C	Option	Levels II, III, or IV evidence, but findings are inconsistent	Clinicians should be flexible in their decision making regarding appropriate practice, although they may set bounds on alternatives; patient preferences should have a substantial influencing role
D	Option	Level V evidence; little or no systematic empirical evidence	Clinicians should consider all options in their decision making and be alert to new published evidence that clarifies the balance or benefit versus harm; patient preference should have a substantial influencing role

Burns, P., Rohrich, R., & Chung, K. (2011). The Levels of Evidence and their role in Evidence-Based Medicine. *Plastic and Reconstructive Surgery*, *128*(1), 305-310.

Cost Analysis:

A cost analysis was not performed and cost analyses were not reviewed.

Method of Guideline Validation:

An external review by a registered anesthesia provider who was not involved in the development of the clinical practice guideline and has no affiliation with the site. The guideline will undergo a peer review every five years to remain current with literature support, equipment, and recommendations.

Stakeholder Involvement:

The Clinical Practice Guideline was developed by Austin Thruston, a student Registered Nurse Anesthetists from The University of Arizona. The goal of the guideline was to provide evidenced based guidelines for monitoring neuromuscular blockade for a local, Arizona anesthesia group. A local anesthesia provider assisted in gathering valuable clinical insight into the development of the guideline. Additional anesthesia providers evaluated and rated the guideline using the AGREE II guideline assessment tool to ensure a high-quality CPG. The goal of the project was to reduce residual paralysis and increase patient safety.

Funding

There was no funding required for completion of this project. The guideline was developed as a project by a Doctor of Nursing Practice Student.

Disclaimer

This guideline was developed using high quality evidence and is to be used as only a guide to practice. Intended users should utilize clinical judgement for each individual patient when using the guideline.

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