

Neuromuscular Monitoring: Does the Use of Acceleromyography Compared With Unaided Clinical Assessment Result in Lower Occurrences of Postoperative Residual Neuromuscular Blockade in Patients Admitted to the Post-Anesthesia Care Unit? A Literature Review

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Abstract

Postoperative residual neuromuscular blockade continues to affect a considerable percentage of patients admitted to the post-anesthesia care unit. Research supports the use of quantitative acceleromyography to monitor neuromuscular blockade and recovery. The purpose of this report was to determine whether objective acceleromyography compared with subjective peripheral twitch monitors and clinical assessment is more effective in decreasing the occurrence of postoperative residual neuromuscular blockade. A literature search was conducted by using ClinicalKey, the Cochrane Collaboration, EMBASE, PubMed, and Proquest. A total of 36 articles met the inclusion criteria, of which 8 were included in the present review. The evidence is consistent in portraying that the use of acceleromyography does decrease the occurrence of residual neuromuscular blockade and it does prevent patients from being reversed at much lower train-of-four ratios. Residual neuromuscular blockade is too often overlooked and considering its substantial consequences should be a reprioritized focus. What remains to be explored is the significance of low-level residual neuromuscular blockade postoperatively.

KEYWORDS: neuromuscular blockade monitoring, respiratory, paralysis, complications, acceleromyography, postoperative complications, twitch monitor, peripheral nerve stimulator.

INTRODUCTION

Postoperative residual neuromuscular blockade continues to affect a considerable percentage of patients admitted to the post-anesthesia care unit (PACU). Recent evidence suggests that 17% to 36% of patients arriving in the PACU present with objective manifestations of incomplete neuromuscular blockade reversal as determined by train-of-four (TOF) ratios less than 0.9.¹ Patients presenting to the PACU with a TOF ratio <0.9 are considered to have residual neuromuscular blockade and are at increased risk for experiencing adverse respiratory events such as reduced upper airway volume, airway obstruction, hypoxemia events, and postoperative pulmonary complications.² Research supports the use of quantitative acceleromyography to monitor neuromuscular blockade and recovery.

Neuromuscular monitoring includes both qualitative monitoring, such as the use of peripheral nerve stimulators and clinical sign assessment (eg, 5-s head-lift test and tongue blade stability between the incisors), and quantitative approaches (eg, acceleromyography). However, the change in practice from qualitative to quantitative monitoring is accompanied by hesitancy and uncertainty from practitioners across the nation who underestimate the occurrence of postoperative residual neuromuscular blockade and its consequences. The rationale for switching from qualitative assessments to a more quantitative approach using accelerometry needs review. The purpose of this report was to determine whether objective acceleromyography compared with subjective peripheral twitch monitors and clinical assessment is more effective in decreasing the occurrence of postoperative residual neuromuscular blockade. A literature review of what current research supports and the current trends regarding the impact of qualitative and quantitative assessment with respect to residual paralysis is provided, and a synthesis of current research follows. A table of the literature cited will be provided as an Appendix for further review.

METHODOLOGY

A literature search was conducted by using ClinicalKey, The Cochrane Collaboration, EMBASE, PubMed, and Proquest. Keywords such as “neuromuscular blockade monitoring,” “respiratory*,” “paralysis,” “complications,” “postoperative residual curarization,” “postoperative complications,” “twitch monitor,” and “peripheral nerve stimulator” were used. The MESH terms “neuromuscular monitoring” and “respiratory” were used for each database search. The key words were also used together by using “AND” (“neuromuscular monitoring AND respiratory,” “neuromuscular monitoring AND respiratory paralysis,” “postoperative complications AND neuromuscular monitoring,” “neuromuscular monitoring AND respiratory AND twitch monitor,” “neuromuscular monitoring AND respiratory postoperative curarization.”) The term OR (“respiratory OR paralysis”) was also used. The search was restricted to the years of 2003 to 2013 and to the specialty of anesthesia. Altogether, the databases yielded 336 citations with some overlap. A total of 36 articles met the inclusion criteria, of which 8 were used for the present review. Reference lists of certain studies were searched manually and showed much overlap.

Inclusion criteria were studies of adults (18 years and older), patients undergoing surgical procedures, patients admitted to the PACU for postoperative monitoring, patients who received neuromuscular blocking agents and were given a TOF ratio for reversal, and patients who were assessed by either a qualitative method or a quantitative method regarding the use of acceleromyography. The exclusion criteria were research specific to children, animals, emergency operations, or cardiac surgeries; review articles; editorials; dissertations; summaries; and foreign studies that could not be translated into English.

Several studies, including the remaining 28 articles found but not included here, discussed the correlation of specific agents (eg, sugammadex, rocuronium, pancuronium) to the incidence of postoperative neuromuscular blockade but did not focus on qualitative versus quantitative monitoring or expressed an opinion that shifted the focus of the study from scientific evidence to a more biased platform. These studies were excluded because they were not exclusive to the anesthesia topic.

LITERATURE REVIEW

A meta-analysis was conducted in 2007 to understand the impact of neuromuscular monitoring on residual neuromuscular blockade.³ Despite previous studies showing an association, the use of intraoperative neuromuscular function monitoring was not shown to decrease the incidence of postoperative residual curarization.³ Since this finding, recent evidence has suggested that residual neuromuscular blockade is present not only at TOF ratios <0.7 but is becoming more frequent at TOF ratios ≤0.9.⁴ Another current study was conducted to determine the incidence of residual neuromuscular blockade at the time of extubation. When standard criteria (5-s head lift or hand grip, following commands, stable ventilatory pattern) were met, tracheal extubation was performed.² Among those individuals undergoing elective surgical procedures, 58% had a TOF ratio <0.7 and 88% had a TOF ratio <0.9 at the time of tracheal extubation.² Furthermore, upon arrival to the PACU, general weakness, 5-s eye

opening and head lift, blurry vision, impaired ability to speak, and suppressed ability to cough were present among patients with a TOF ratio <0.9 compared with those with a TOF ratio >0.9.^{2,4}

In another study, objective data obtained by bedside evaluation in the PACU did not predict the occurrence of residual paralysis when compared with subjective data.⁵ Murphy et al discovered that the “presence or absence of symptoms (difficulty swallowing, dysarthria, visual disturbances) of muscle weakness was predictive of the presence or absence of a TOF ratio greater than 0.90, but the presence or absence of signs (5-second head-lift test, protrusion of tongue, swallowing ability, opening of eyes) of muscle weakness was not.”⁵(p951) Therefore, bedside evaluations are not sensitive enough to confidently rule out residual postoperative neuromuscular blockade, which may account for the inaccuracy associated with the use of qualitative evaluation. If patients are still susceptible to experiencing residual paralysis at the current standard (TOF ratio ≥0.9), the use of acceleromyography will identify these patients and may reduce the occurrence of residual neuromuscular blockade. Perhaps the focus for prevention of residual paralysis should not be based on the conventional and convenient qualitative method of peripheral twitch count but rather on the sensitivity and reliability of qualitative versus quantitative evaluation to adequately assess TOF ≥ 0.9.

The occurrence of residual paralysis is nondiscriminatory at the current benchmark for reversal of a TOF ratio ≥ 0.9. The evidence Murphy et al⁵ present in which clinical tests such as the 5-s head lift test or handgrip were used to reverse patients at the time of tracheal extubation can also be maintained at a TOF ratio ≤ 0.9. The presentation of postoperative residual neuromuscular blockade is associated with a broad window. Residual neuromuscular blockade is present and may be symptomatic at TOF ratios ≤ 0.9. TOF ratios as low as <0.4 may have TOF count fade that is not easily discerned.¹ Therefore, it is possible that anesthesia practitioners who rely solely on peripheral nerve stimulator TOF count may be reversing patients from a deeper level of neuromuscular block than assumed by use of subjective assessment. Similarly, using TOF count and subjective assessment of fade may miss residual neuromuscular blockade postoperatively.

Capron et al⁶ conducted a study to determine if the use of acceleromyographic TOF ratios could detect residual paralysis with 95% probability. The results of this study in which patients were randomly assigned to a control group or an acceleromyography monitoring group revealed that acceleromyography could not detect postoperative residual neuromuscular blockade with 95% probability at a TOF ratio less than 0.9 but could reliably detect it at TOF ratios equal to 0.95 and 1.0.⁶

Residual neuromuscular blockade is a worldwide problem, yet it is incorrectly considered rare by many health care professionals. A Portuguese study reported that 91 of 350 patients showed a TOF ratio less than 0.9 on arrival in the PACU, giving an incidence of residual neuromuscular blockade of 26%.⁷ This percentage falls within the broad gap of 17–36% revealed by previous studies. Not only do these data provide congruency of this unfortunate percentage, but the study also reported that “there were no statistically significant differences in the occurrence of residual

blockade relating to the neuromuscular blocker used.”⁷(p3) The use of intermediate-acting neuromuscular blockers was thought to lower or eliminate the risk of residual paralysis. This is not true. The data suggest that the occurrence of patients being admitted to the PACU with residual neuromuscular blockade is being under-identified and that reliance on clinical signs alone is insufficient to identify all cases of residual paralysis.

A survey conducted among practitioners in the United Kingdom revealed that only 28% use peripheral neuromuscular monitors, whereas 42% use measurements similar to the 5-s head lift test as the diagnostic criteria for extubation.⁸ A poll conducted in the United States showed that only 12% use quantitative monitors to assess a patient's readiness for recovery. Of the individuals polled, only 28.8% were correct in selecting TOF ratios > 0.9 as the standard for extubation criteria in the effort to avoid residual neuromuscular blockade.⁸

The evidence is consistent in portraying that the use of acceleromyography does decrease the occurrence of residual neuromuscular blockade and it does prevent patients from being reversed at much lower TOF ratios. However, the fact remains that postoperative residual neuromuscular blockade can still occur at a TOF \geq 0.9. Acceleromyography has been shown to reduce the occurrence of postoperative complications such as difficulty maintaining airway patency, yet has not been shown to eradicate its occurrence completely. At the current standard, acceleromyography is still susceptible to the occasional event of postoperative residual neuromuscular blockade, despite the lower occurrence than with qualitative assessment. Consequently, the current standard is still being accepted for reversal. Acceleromyography research has not only been useful in residual neuromuscular blockade research but has also contributed to the idea that the current TOF ratio is not sufficient for the goal of preventing postoperative residual neuromuscular blockade. Acceleromyography is useful in regards to outcomes research to assess the incidence of postoperative residual neuromuscular blockade and the theme that when not used preventable complications can arise seems to resonate in the literature.

CONCLUSION

Inconsistency in assessment of peripheral twitch monitoring data and the correlation of these data to clinical signs allows varying degrees of postoperative residual neuromuscular blockade. If the central focus is to maintain the safety and comfort of the patient, the current standard of a TOF ratio \geq 0.9 should be reevaluated, and acceleromyography must be used because peripheral twitch monitors do not provide a TOF ratio but rather only a TOF count. Residual neuromuscular blockade is too often overlooked and considering its substantial consequences should be a reprioritized focus. Residual neuromuscular blockade is a preventable patient safety problem.³ It is imperative that clinicians be equipped with the appropriate tools to adequately assess interventions. The complex nature of residual neuromuscular paralysis will make it “difficult to differentiate the adverse physiologic effects resulting from incomplete neuromuscular recovery from the residual effects of opioids, benzodiazepines, volatile anesthetics, or anesthesia induction drugs.”⁹(p122) Therefore, consideration of objective accelerometry use and increasing the standard of “full reversal” to a TOF > 0.95 or = 1.0 needs to be considered. From the aspect of patient safety, acceleromyography is a much better tool to use than peripheral twitch monitors and certainly unaided clinical assessment.

Although complications occurring in the PACU are listed, problems or events beyond the PACU have not been described in great detail.

The idea that postoperative residual neuromuscular blockade results in postoperative morbidity is the current speculation in the absence of sufficient scientific data. Sufficient research has presented correlations among TOF ratios and clinical signs and symptoms and acceleromyography versus qualitative data with respect to postoperative residual neuromuscular blockade, yet there is no evidence as to how postoperative residual neuromuscular blockade impacts patient prognosis beyond the immediate period of the postoperative PACU stay. Is recovery discharge prolonged as a result of the patient's experiencing postoperative residual neuromuscular blockade? Is the experiencing of unexpected complications by the patient extraneous to the surgical procedure done as a result of experiencing residual neuromuscular blockade in the PACU? Data are lacking pertaining to the complications associated with low degrees of postoperative residual neuromuscular blockade and how it impacts patient prognosis and quality of life in terms of days, months, and years.

The biggest concern is that anesthesia practitioners underestimate the occurrence and possibly the severity of postoperative residual neuromuscular blockade. Cost analyses and outcomes studies with respect to low-level postoperative neuromuscular blockade (TOF ratios 0.85 to < 0.95 vs. TOF \geq 0.95 or = 1.0) may be the tipping point to change practice from subjective peripheral twitch monitoring or clinical assessment alone to objective acceleromyographic measurement.

The answer to the question, Is objective acceleromyography compared with subjective peripheral twitch monitoring and clinical assessment more effective in decreasing the occurrence of postoperative residual neuromuscular blockade? is “yes.” What remains to be explored is the significance of low-level residual neuromuscular blockade postoperatively. Further investigation is warranted and ongoing.

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Appendix I: Annotated Bibliography Table								
Author, Date	Study purpose/ research ques- tion	Study Design	Theory/ Framework model	Sample & Setting Description, Size (n)	Data Collection Methods	Primary Outcome Variables	Results	Comments
Murphy GS, Szokol JW, Avram MJ, et al (2013) ^a	Determine incidence and severity of symptoms of muscle weakness in patients with and without residual neuromus- cular blockade.	Randomized clinical trial	None cited	55 patients un- dergoing elective surgical proce- dures requiring neuromuscular blockade, with an anticipated dura- tion of at least 60 minutes	Testing for objective evidence of muscle weakness (signs) fol- lowed by an exam- ination for subjective evidence of residual paresis (symptoms). Each patient was assessed for 16 symptoms and 11 signs of muscle weakness at each testing time at arrival to PACU, 20 min, 40 min, & 60 min after.	The incidence of symptoms and the incidence of signs of muscle weakness were defined as the presence of 1 symptoms or signs, respec- tively, at each of the 4 testing times in the TOF <0.9 and TOF >0.9 cohorts.	The incidence and severity of muscle weakness were significantly greater in patients with TOF ratios <0.9 during the first 60 minutes of the PACU stay.	Signs of muscle weakness were observed less frequently than symptoms. The findings from the present investiga- tion demonstrate that incomplete neuromuscular re- covery is a primary risk factor for un- pleasant symptoms of postoperative weakness.
Murphy GS, Szokol JW, Avram MJ, et al (2011) ^b	Acceleromyography monitoring would diminish unpleas- ant symptoms of residual paresis during recovery from anesthesia by reduc- ing the percentage of patients with TOF <0.9.	Randomized clin- ical trial to either acceleromyography (quantitative) or TOF (conventional quali- tative monitoring)	None cited, but the design was based on the findings of Kop- man et al from a study conducted in 1997.	155 patients un- dergoing elective surgical proce- dures requiring NMB for at least 60 min were tele- phoned the day before surgery for consent at a tertiary medical facility	TOF Watch SX was placed on patients in the OR and was randomized to the acceleromyography or conventional TOF group. Ratios and evaluation of s/s were taken at admit, 20, 40, 60 min.	Overall weak- ness scores, total number of symptoms of muscle weakness, total number of signs of muscle weak- ness at four time intervals during the stay in the PACU.	TOF ratios in the acceleromyography group at all time in- tervals were higher and presented with fewer symptoms of muscle weakness in comparison to the control group. The presence of objective s/s was a poor determinant of PORC compared to subjective data provided by patient surveys.	Although TOF ratios <0.9 indicate adequate response time, subjective data presented by this study propose a new dilemma that the degree of blockade observed is less than what is perceived.
Sauer M, Stahn A, Soltesz S, No- eldge-Schom- burg G, & Mencke T (2011) ^c	The incidence of critical respira- tory events, such as hypoxemia, in patients with minimal residual neuromus- cular blockade and comparison of these data with those from patients with full re- covery of blockade.	Randomized, prospective, place- bo-controlled trial	None cited; how- ever, the author does cite findings from Murphy et al reporting a high incidence of severe residual neuromuscular blockade- criti- cal respiratory events in patients with early POPC in the PACU. This seems to be the basis for this study.	132 adult patients, aged 18–80 years, with American Society of Anesthesiolo- gy I–III physical status, undergo- ing orthopedic surgery under general anaes- thesia, including rocuronium to produce neuro- muscular block- ade; 114 patients were randomized to one of two groups: neostig- mine group (neostigmine) or placebo group (saline).	PNS and acceler- omyography were used to determine TOF ratios. Patients were randomized to neostigmine (to be reversed at ratio > 1) or placebo group (to be reversed at ratio <1). In the PACU s/s were assessed along with the oc- currence of adverse respiratory events or hypoxemia.	s/s of muscle weakness and the occurrence of critical respira- tory events	Minimal residual block was associat- ed with a higher incide- nce of hypoxemia in the PACU. Critical respiratory events, such as postoper- ative respiratory insufficiency and nonspecific respi- ratory problems, were not observed. Among signs and symptoms of muscle weakness, swal- lowing difficulties occurred more often in the patients with a minimal residual block compared with patients with full recovery of neuro- muscular block.	This study is the first randomized, prospective, placebo-controlled investigation to examine the impact of residual neuro- muscular blockade on postoperative morbidity. However, the evidence does not provide new insight regarding the impact PORC can have in postoper- ative morbidity since its study sample was restricted to neostigmine and did not provide ad- ditional information beyond the PACU length of stay.
Capron F, Alla F, Hottier C, Meistelman C, Fuchs-Buder T (2004) ^d	To determine whether the accel- eromyographic TOF ratio detects residual paralysis with a 95% probability.	Randomized clinical trial	None cited; how- ever, the authors utilize evidence resulted by Harp- er et al regarding (monitoring) dif- ferences as the basis for the aim of the study.	60 adult patients undergoing elective surgical procedures un- dergoing tracheal intubation	Random selection to group A (acceleromy- ography calibration) and group B (non- calibrated). Negative predictive values were calculated for detecting residual paralysis at ratios 0.9, 0.95, and 1.0.	Ratio values correlating with the detection of residual paralysis	Acceleromyog- raphy is unlikely to significantly improve detection of residual paralysis, at the TOF of 0.9. Increasing TOF recovery to 0.95 and 1.0 increased the negative predictive values in group A to 70% and 97%.	Overall, the use of acceleromyogra- phy can impact the detection of residual paralysis once the standard is raised to 0.95 or 1.0, but cali- bration prior to NMB must be performed.
Murphy GS, Szokol JW, Marymont JH, Franklin M, Avram MJ, Vender JS (2005) ^e	Assess TOF ratios immediately before tracheal extubation, when clinicians had determined that full recovery of neuro- muscular function had occurred using standard clinical criteria.	Outcomes study	None cited. Since "no previous studies have examined the incidence and se- verity of residual neuromuscular block at the time of tracheal extubation," this can be used as the foundation of this study.	"123 patients scheduled for elective gynecologic or general surgical proce- dures, between the ages of 18 and 69 yr."	"Standard clinical criteria (5-s head lift or hand grip, eye open- ing on command, negative inspiratory force, vital capacity breath) and peripheral nerve stimulation, acceleromyography, VAS scale"	Presence of s/s of residual paralysis, TOF ratios at time of tracheal extuba- tion, pain per the VAS scale during stay in PACU.	"Acceptable neuro- muscular recovery (TOF ratio > 0.9) was present in only a small percentage (12%) of patients immediately before removal of the endo- tracheal tube." 58% had a TOF ratio <0.70 and 88% had a TOF ratio <0.90 at the time of tracheal extubation. Ratios were significantly lower at the time of extubation in comparison to stay in the PACU.	Acknowledging re- sidual paralysis can occur between TOF of 0.70 and 0.90, it is appropriate to consider changing the standard to achieve TOF >0.90.
Esteves SO, Martins M, Barros F, et al (2013) ^f	"Determine the inci- dence of incomplete postoperative neu- romuscular recovery (defined by a TOF ratio less than 0.9) from anesthesia at PACUs in Portu- guese hospitals."	Multicenter observa- tional study	No specific framework, but "no large-scale study about the frequency of RNMB in Portu- gal."	Adult patients scheduled for elective surgery requiring general anaesthesia with neuromuscular blocking agents between July and November 2010. A total of 350 patients were used.	Patients who gave consent were moni- tored using the TOF Watch SX and were categorized into two groups according to TOF ratios (of at least 0.90 and less than 0.90).	The presence of residual paraly- sis in PACU and corresponding TOF ratios.	"Ninety-one patients had a train-of-four ratio less than 0.9 on arrival in the pos- tanaesthesia care unit, an incidence of residual neuromus- cular blockade of 26%."	"There were no statistically signifi- cant differences in the occurrence of RNMB according to the neuromuscular blocker used."
Grayling M & Sweeney BP (2007) ^g	To determine current anesthetic prac- tice with respect to neuromuscular monitoring	Prospective survey	None cited	The questionnaire was distributed to a total of 715 consultants, trainees, and nonconsul- tant career grades anesthetists at 5 teaching hospitals and 7 district hospitals in the United Kingdom.	"Respondents were asked to supply de- tails regarding their use of peripheral nerve stimulators in the context of neuro- muscular blockade reversal; including type of monitor and the parameters (i.e., train-of-four [TOF] ratio) deemed to be acceptable for extu- bation. In addition, for those anaesthe- tists who did not use a monitor, informa- tion was sought regarding the clinical tests routinely per- formed at the end of surgery."	Peripheral nerve stimulator usage, TOF ratio standard for extubation, other "criteria used for suitability for extubation."	28% use PNS occasionally during routine practice, 62% stated they never use it, 74.7% stated standard TOF ratio for extubation is >0.70, 28.8% stated standard TOF ratio for extubation is >0.90. The 5-s head lift test was used by 42% and pattern of respiration was used by 36% when PNS was not used for extubation. Finally, 17% state neuromuscular moni- toring similar to the PNS should be used in practice.	The survey provides a quick glance of the consensus regarding neuro- muscular monitoring practice; however, it would be interesting to see how many of the respondents believe PORC is directly impacted by the use or ill-use of PNS. Overall, it does provide the reader with an idea of how extubation criteria are deter- mined.
Naguib M, Kopman AF, Ensor JE (2007) ^h	Examine the effect of intraoperative monitoring of neu- romuscular function on the incidence of PORC	Meta-analysis	Random effects model	Data were analyzed from 24 studies (13 randomized and 11 observational studies).	Electronic literary search of various databases (PubMed, Cochrane Controlled Trials Register, Web of Knowledge) from 1975-2006.	Incidence of PORC	"Neuromuscular function was moni- tored in 823 patients (24.4%). A simple peripheral nerve stimulator was used in 543 patients, and an objective monitor was used in 280."	"We could not demonstrate the use of an intraoper- ative neuromuscular function monitor decreased the inci- dence of PORC."

Abbreviations: NMB, neuromuscular blockade; OR, operating room; PACU, post-anesthesia care unit; PNS, peripheral nerve stimulation; POPC, postoperative pulmonary complication; PORC, postopera- tive residual curarization; RNMB, residual neuromuscular blockade; s/s, signs and symptoms; TOF, train-of-four.

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