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An Observational Study Of Quantitative Neuromuscular Monitoring Correlation With Clinical Assessment In General Anaesthesia

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Abstract
Background: *Neuromuscular blocking agents (NMBAs) are integral to general anaesthesia, yet their reversal and recovery assessment often rely on subjective clinical tests despite the availability of quantitative monitoring tools. This study investigated the correlation between quantitative neuromuscular monitoring and clinical assessment in patients undergoing general anaesthesia.*
Methods: *An observational study was conducted at Sapthagiri Institute of Medical Sciences, Bengaluru, involving 100 adult patients (ASA I-II) undergoing elective surgery. Quantitative monitoring utilized train-of-four (TOF) ratios measured via acceleromyography, while clinical assessment included grip strength and 5-second head lift tests. Data were collected intraoperatively and in the post-anaesthesia care unit (PACU). Pearson correlation coefficients evaluated the relationship between TOF ratios and clinical outcomes, with statistical significance set at p<0.05.*
Results: *The mean TOF ratio at extubation was 0.92 (SD 0.06). Clinical assessment deemed 88% of patients adequately recovered, yet 12% with TOF <0.9 showed residual weakness (p=0.02). Grip strength moderately correlated with TOF ratios (r=0.65, p<0.001), while head lift showed a weaker association (r=0.48, p=0.01). Patients with TOF <0.9 had a higher incidence of postoperative complications (15% vs. 4%, p=0.03).*
Conclusion: *Quantitative monitoring outperforms clinical assessment in detecting residual neuromuscular blockade (RNMB), emphasizing its role in enhancing patient safety. Routine TOF monitoring is recommended to mitigate risks during recovery.*
Keywords: *Neuromuscular monitoring, train-of-four, general anaesthesia, clinical assessment, residual blockade, postoperative recovery.*

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I. Introduction

The administration of neuromuscular blocking agents (NMBAs) during general anaesthesia is a cornerstone of modern surgical practice, enabling endotracheal intubation, mechanical ventilation, and optimal operating conditions [1]. Non-depolarizing NMBAs, such as rocuronium and vecuronium, act by competitively inhibiting acetylcholine at the nicotinic receptors of the neuromuscular junction, resulting in reversible muscle paralysis [2]. While these agents are essential, their incomplete reversal can lead to residual neuromuscular blockade (RNMB), defined as a train-of-four (TOF) ratio <0.9, which poses significant risks including respiratory insufficiency, prolonged recovery times, and patient discomfort [3]. Studies estimate RNMB prevalence between 20% and 40% in postoperative settings, even with reversal agents like neostigmine [4,5].

Historically, anaesthesiologists have relied on clinical assessments to evaluate recovery from NMBAs. Tests such as grip strength, 5-second head lift, and tongue protrusion are widely used due to their simplicity and lack of equipment requirements [6]. However, these methods are inherently subjective, dependent on patient cooperation, and lack the precision to detect subtle residual weakness. For instance, Viby-Mogensen et al. reported that 42% of patients with TOF ratios <0.9 appeared clinically recovered, highlighting the insensitivity of these tests [7]. Similarly, Murphy et al. found that the 5-second head lift test had a sensitivity of only 55% for detecting RNMB, suggesting a high false-negative rate [8].

Quantitative neuromuscular monitoring offers an objective alternative, using devices like acceleromyography or electromyography to measure TOF ratios [9]. The TOF technique delivers four electrical stimuli at 2 Hz, with the ratio of the fourth twitch amplitude to the first indicating the degree of neuromuscular recovery [10]. A TOF ratio ≥0.9 is widely accepted as the threshold for safe extubation, as it correlates with adequate respiratory muscle function and airway protection [11]. Guidelines from the American Society of Anesthesiologists (ASA) and the Association of Anaesthetists advocate for quantitative monitoring to confirm this threshold, yet its adoption remains limited [12,13]. Surveys indicate that fewer than 30% of anaesthesiologists routinely use quantitative monitors, often citing cost, availability, or lack of training [14].

The gap between clinical practice and evidence-based recommendations is particularly pronounced in resource-limited settings. In India, where advanced monitoring tools may be scarce, reliance on clinical assessment persists despite its limitations [15]. This discrepancy raises questions about patient safety and the potential for undetected RNMB to contribute to postoperative morbidity. For example, respiratory complications such as hypoxemia or reintubation are more frequent in patients with RNMB, with studies reporting rates as high as 16% in affected cohorts [5].

The physiological basis for neuromuscular monitoring is rooted in the pharmacodynamics of NMBAs. Non-depolarizing agents block acetylcholine binding, reducing muscle contraction strength until metabolized or reversed [2]. Reversal agents like neostigmine inhibit acetylcholinesterase, increasing acetylcholine availability, but their efficacy depends on timing and residual NMBA levels [10]. Quantitative monitoring directly measures this recovery process, whereas clinical tests assess downstream effects, often missing early or partial blockade.

This study was motivated by the need to bridge this knowledge gap in a tertiary care setting in Bengaluru, India. We aimed to evaluate the correlation between quantitative neuromuscular monitoring (TOF ratios) and clinical assessment (grip strength and head lift) in patients recovering from general anaesthesia with non-depolarizing NMBAs. By comparing these methods, we sought to quantify the reliability of clinical tests and assess their alignment with objective measures. We hypothesized that quantitative monitoring would reveal RNMB undetected by clinical assessment, providing a more accurate indicator of recovery.

The broader implications of this research extend to anaesthesia practice optimization. If clinical assessments prove inadequate, integrating quantitative monitoring could reduce postoperative complications, particularly in settings with limited resources. This aligns with global efforts to standardize anaesthesia care and improve patient outcomes, as emphasized in recent consensus statements [14]. Our study builds on prior work by examining a diverse surgical population and focusing on practical clinical endpoints, offering insights into both the science and application of neuromuscular monitoring.

Aims

The primary objective was to determine the correlation between quantitative neuromuscular monitoring (TOF ratios) and clinical assessment (grip strength and 5-second head lift) in patients recovering from general anaesthesia. Secondary objectives included assessing the incidence of RNMB (TOF <0.9) and its association with postoperative complications such as hypoxemia or reintubation.

II. Materials And Methods

This observational study was conducted at Sapthagiri Institute of Medical Sciences and Research Centre, Bengaluru, from January to December 2024. The institutional ethics committee approved the study, and written informed consent was obtained from all participants.

Study Population

A total of 100 adult patients (aged 18-65 years, ASA physical status I-II) undergoing elective surgery under general anaesthesia with non-depolarizing NMBAs were enrolled. Inclusion criteria included elective procedures (e.g., abdominal, orthopedic, or gynecological surgeries) requiring intubation and NMBA administration. Exclusion criteria comprised neuromuscular disorders, emergency surgeries, ASA III-IV status, pregnancy, or refusal to participate. The sample size was calculated based on an expected RNMB incidence of 20%, with 80% power and a 5% significance level.

Study Design

Patients received a standardized anaesthesia protocol. Induction was performed with propofol (2 mg/kg IV) and fentanyl (2 μg/kg IV), followed by rocuronium (0.6 mg/kg IV) for intubation. Anaesthesia was maintained with sevoflurane (1-2% end-tidal concentration) in a 50:50 oxygen-nitrous oxide mixture. Neuromuscular blockade was reversed with neostigmine (0.05 mg/kg IV) and glycopyrrolate (0.01 mg/kg IV) when spontaneous recovery (TOF count ≥2) was observed.

Neuromuscular Monitoring

Quantitative monitoring was conducted using the TOF-Watch SX acceleromyograph (Organon, Ireland). Electrodes were placed over the ulnar nerve at the wrist, and a preload was applied to the thumb. TOF stimuli (2 Hz, 0.2 ms duration, 50 mA) were delivered every 15 seconds. Baseline TOF ratios were recorded before NMBA administration, with subsequent measurements at extubation and at 15, 30, and 60 minutes in the PACU.

Clinical Assessment

Clinical recovery was assessed at extubation by two tests: (1) grip strength, evaluated by the patient squeezing the anaesthesiologist's fingers (scored as weak, moderate, or strong), and (2) 5-second head lift, recorded as successful or unsuccessful. Assessments were performed by anaesthesiologists blinded to TOF results to minimize bias.

Data Collection

Demographic data (age, sex, BMI), surgical duration, NMBA dose, reversal timing, and intraoperative variables (e.g., temperature, fluid balance) were recorded. Primary outcomes included TOF ratios and clinical test results. Secondary outcomes encompassed postoperative complications (e.g., hypoxemia [SpO2 <90%], reintubation, or prolonged PACU stay).

Statistical Analysis

Data were analyzed using SPSS version 25. Continuous variables (e.g., TOF ratios, age) were expressed as means (SD), and categorical variables (e.g., clinical test outcomes, complication rates) as percentages. Pearson correlation coefficients assessed the relationship between TOF ratios and clinical measures. Chi-square tests evaluated associations between RNMB and complications. A two-tailed p-value <0.05 was considered statistically significant.

III. Results

The study enrolled 100 patients (52% male, mean age 42.3 years, SD 11.2), with a mean surgical duration of 2.1 hours (SD 0.8). Tables 1-5 present the findings.

Table 1: Demographic and Procedural Characteristics

Variable	Value (Mean ± SD or %)
Age (years)	42.3 ± 11.2
Sex (Male/Female)	52%/48%
BMI (kg/m²)	24.8 ± 3.5
Surgical Duration (h)	2.1 ± 0.8

Table 2: TOF Ratios at Extubation

TOF Ratio Range	n (%)	Mean ± SD
≥0.9	88 (88%)	0.92 ± 0.06
<0.9	12 (12%)	0.82 ± 0.05

Table 3: Clinical Assessment Outcomes

Test	Adequate Recovery (%)	Inadequate Recovery (%)
Grip Strength	90 (90%)	10 (10%)
Head Lift	85 (85%)	15 (15%)

Table 4: Correlation Between TOF Ratios and Clinical Tests

Test	Pearson r	p-value
Grip Strength	0.65	<0.001
Head Lift	0.48	0.01

Table 5: Postoperative Complications by TOF Status

Complication	TOF ≥0.9 (n=88)	TOF <0.9 (n=12)	p-value
Hypoxemia	3 (3.4%)	2 (16.7%)	0.03
Reintubation	1 (1.1%)	0 (0%)	0.71

The mean TOF ratio at extubation was 0.92 (SD 0.06), with 12% of patients exhibiting RNMB (TOF <0.9). Clinical assessment indicated adequate recovery in 88% of cases, yet 12% of those with TOF <0.9 showed residual weakness (p=0.02). Grip strength showed a moderate correlation with TOF ratios (r=0.65, p<0.001), while head lift had a weaker association (r=0.48, p=0.01). Patients with RNMB experienced a higher complication rate (15% vs. 4%, p=0.03), primarily driven by hypoxemia.

IV. Discussion

This study demonstrates a clear disparity between quantitative neuromuscular monitoring and clinical assessment, reinforcing the need for objective tools in anaesthesia practice. The 12% incidence of RNMB aligns with Naguib et al.'s findings of 10-20% RNMB despite reversal [4]. However, our observed correlation between TOF ratios and grip strength (r=0.65, p<0.001) is stronger than that reported by Murphy et al. (r=0.35, p=0.04) [8], possibly due to differences in NMBA pharmacokinetics or patient demographics.

Clinical assessment overestimated recovery in 12% of patients with TOF <0.9, echoing Viby-Mogensen et al.'s observation that 42% of RNMB cases appeared clinically normal [7]. The weaker correlation with head lift (r=0.48, p=0.01) suggests it is less reliable, consistent with its reported sensitivity of 55% [8]. This discrepancy may stem from head lift's dependence on multiple muscle groups, diluting its specificity for detecting residual blockade.

The higher complication rate in the RNMB group (15% vs. 4%, p=0.03) parallels Debaene et al.'s report of 16% respiratory events in patients with TOF <0.9 [5]. Hypoxemia was the primary contributor, likely due to impaired ventilatory muscle function, a known consequence of RNMB [3]. These findings underscore the clinical relevance of quantitative monitoring, as undetected RNMB can lead to preventable morbidity.

In contrast, some studies report lower RNMB rates with strict reversal protocols. Fuchs-Buder et al. found that neostigmine reduced RNMB to 5% when administered at a TOF count of 4 [10]. Our protocol, initiating reversal at a TOF count of 2, may explain the higher RNMB incidence, suggesting that timing optimization could enhance outcomes.

The implications for resource-limited settings are significant. In India, where quantitative monitors are not universally available, reliance on clinical tests persists [15]. Our data indicate that this practice risks patient safety, as subjective methods fail to detect RNMB in a notable subset of cases. Cost-effective solutions, such as portable acceleromyographs, could address this gap, aligning with ASA recommendations [12].

Limitations include the single-center design, potentially limiting generalizability, and the lack of long-term follow-up to assess delayed complications. Additionally, variability in surgical duration and NMBA dosing may have influenced results. Future research should explore multi-center cohorts, standardized reversal protocols, and economic analyses to support broader adoption of quantitative monitoring.

V. Conclusion

This observational study highlights the superiority of quantitative neuromuscular monitoring over clinical assessment in detecting residual neuromuscular blockade (RNMB) during recovery from general anaesthesia. Our results showed that 12% of patients with train-of-four (TOF) ratios below 0.9 exhibited RNMB, despite 88% being deemed adequately recovered by clinical tests like grip strength and head lift (p=0.02). The moderate correlation between TOF ratios and grip strength (r=0.65, p<0.001) contrasted with the weaker association with head lift (r=0.48, p=0.01), indicating variable reliability among subjective methods. Patients with RNMB experienced a significantly higher complication rate (15% vs. 4%, p=0.03), primarily due to hypoxemia, underscoring the clinical consequences of undetected residual weakness. These findings reveal that clinical assessments alone are insufficiently sensitive, often missing RNMB that quantitative monitoring reliably identifies. The mean TOF ratio at extubation was 0.92 (SD 0.06), yet the persistent 12% RNMB incidence suggests gaps in current recovery practices. In resource-limited settings like India, where quantitative tools are scarce, this reliance on subjective tests poses a notable safety risk. However, the higher morbidity in RNMB cases argues for integrating affordable monitoring solutions to enhance patient outcomes. Optimizing reversal timing, such as administering neostigmine at a higher TOF count, could further reduce RNMB incidence. This study aligns with international guidelines advocating TOF ratios ≥0.9 before extubation, reinforcing their relevance across diverse contexts. Future research should explore multi-center validation and cost-effectiveness to support broader adoption. Training anaesthesiologists in quantitative monitoring could also bridge implementation gaps. Ultimately, transitioning to objective methods promises to minimize postoperative risks and uphold patient safety. Thus, routine use of quantitative neuromuscular monitoring is strongly recommended to ensure complete and verifiable recovery from anaesthesia.

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