REVIEW ARTICLE

Prevention or Overcome: Residual Neuromuscular Blockade—A Narrative Review

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Abstract

The incidence of residual paralysis remains high in the postoperative period even after reversal of intermediate-acting neuromuscular blockers when reversal and extubation are done based on clinical features and are minimized with neuromuscular monitoring (NMM). Correlation between the clinical features of neuromuscular recovery and train-of-four ratio (TOFR) in NMM is variable. Complete neuromuscular recovery depends upon various factors such as age, the weight of the patient, and anesthesia-related factors such as depth of neuromuscular blockade, an inhalational agent used, the time interval between the last dose of neuromuscular block, and reversal administration. The incidence of residual paralysis was found to be high when the neuromuscular blockade was reversed with a standard dose of reversal and recent studies have demonstrated that low-dose neostigmine is adequate to reverse the shallow neuromuscular blocking effects. Hence, quantitative NMM should be used for safe practice while conducting general anesthesia.

Keywords: Neuromuscular monitoring, Neuromuscular recovery, Residual neuromuscular paralysis, Reversal of neuromuscular blockade, Train-of-four ratio.

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Introduction

Neuromuscular blocking agents are used to improve airway management and facilitate the entire surgical procedure and at the end of the surgery, their effects are reversed with anticholinesterase. Recovery from neuromuscular blocking drugs can be confirmed by clinical signs and neuromuscular monitor. However, 39–64% of patients were found with evidence of residual neuromuscular blockade (RNMB) in the post-anesthetic care unit (PACU).[1,2] Studies had demonstrated that when quantitative neuromuscular monitoring (NMM) was applied in the intraoperative period the incidence of residual paralysis was less.[3,4] However, the neuromuscular monitor device is not widely available and only 9.4–22.7% of clinicians had a quantitative train-of-four (TOF) monitoring in their practice.[5,6] Residual neuromuscular blockade is a preventable anesthetic complication. Studies had shown that even a minimal degree of residual muscle weakness may produce a life-threatening postoperative complication.[7] This review is to discuss the correlation between the clinical signs and train of four ratio (TOFR) and effects of RNMB and the significance of prevention of RNMB in clinical practice.

Materials and Methods

We have performed a literature search in PubMed, Google Scholar, Research Gate, and ProQuest by using keywords like "residual neuromuscular paralysis", neostigmine, neuromuscular monitoring, train of four ratio. Randomized controlled trials, cohort studies, and review articles that contained studies and reviews based on residual neuromuscular paralysis were chosen.

Criteria for Neuromuscular Recovery and Correlation between the Clinical and Neuromuscular Monitor

Clinical Features of Neuromuscular Recovery

When the patient is conscious and cooperative most believed the reliable clinical signs of neuromuscular recovery as the ability to wide open their eyes, perform protrusion of tongue, to do sustained handgrip and head lift, and perform leg raising and cough effectively. Whereas in an unconscious, spontaneous breathing person assessment of respiratory variables such as vital capacity (VC), tidal volume, and inspiratory force would also be helpful as neuromuscular recovery.[8,9]

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Neuromuscular Monitoring Criteria for Neuromuscular Recovery

As per NMM initially, TOFR >0.7 was considered as an adequate reversal from neuromuscular blockade. Recent studies have shown that patients have impaired airway reflexes, reduced hypoxic ventilator response when the TOFR is between 0.7 and 0.9. Hence, TOF >0.9 is now accepted as the gold standard for neuromuscular recovery.

Correlation between Clinical Features and Neuromuscular Monitor

The head lift test was proposed as a reliable test for assessing neuromuscular recovery by Dam and Guldmann in 1961 and sustained head lift for 5 seconds was considered as equivalent to

TOFR 0.5 to 0.7. He also demonstrated that no patient could lift the head from the table at a TOFR of 0.4 or less.[10] Viby-Mogensen also demonstrated that at TOFR of 0.6 patient can perform sustained head lift for 3 seconds.[11] However, Adekanye found that respiratory variables such as VC breaths and force of inspiration were often be reduced at a TOFR of 0.6.[12] Kopman and Eikermann demonstrated patients with normal VC breaths and inspiratory force at a TOFR of 0.8 and more.[13] In 2010, Fuchs-Buder et al. concluded that the tongue depressor test was the most sensitive clinical sign for assessing neuromuscular recovery, and a TOFR of >0.8 was required to perform it.[7] Fuchs-Buder et al. in 2016 concluded that clinical signs and respiratory variables used in practice are unreliable in assessing neuromuscular recovery.[14]

Incidence of Anesthesiologist Using a Neuromuscular Monitor in their Clinical Practice around the Globe

Though NMM has been in clinical practice for over 60 years its use is very much limited especially in low-income countries.[15] Survey by Naguib et al. had shown that 19.3 and 9.4% of the European and American anesthesiologists, respectively, do not use neuromuscular monitors routinely and most respondents from both Europe and the US did not believe that either conventional nerve stimulators or quantitative TOF monitor should be part of minimal monitoring standards.[5] Surveys on clinicians had reported that 43% in Denmark, 28% in Germany, 10% in the United Kingdom, and 2% in Mexico only use neuromuscular monitors routinely.[6,16–18] Fifty percent of Italian anesthesiologists used NMM in daily practice and a survey showed that in Australia and New Zealand 60% of practitioners used NMM at least once a month, and 10% never used one in their practice.[19] In France, after a single intubating dose of neuromuscular blocking 52% of anesthesiologists apply NMM regularly.[20]

RNMB in PACU

Studies describing the incidence of RNMB when reversed based on clinical features and NMM are illustrated in Table 1.

Table 1: Studies describing the incidence of RNMB when the intermediate-acting neuromuscular blockade was reversed based on clinical features and neuromuscular monitoring

S. no.	*Study*	*RNMB with clinical signs*	*TOFR described as RNMB*	*RNMB with NMM*
1	Gatke et al.	16.8%	<0.8	3%
2	Debaene et al.		<0.9	45%, 16%
3	Fortier et al.	63.5%		
4	Wardhana et al.	16.7%		2.8%
5	Bailard et al.	42%	<0.7	
6	Kim et al.	24.7%, 14.7%		
7	Murphy et al.	30%	<0.9	
8	Maybauer et al.	57%, 42%	<0.9	
9	Hailu yimer tawuye		<0.7, <0.9	10%, 37%
10	Esteves et al.			30%
11	Murphy			57.7% in elderly, 30% in young

Hazards of RNMB

Residual neuromuscular block in the postoperative period has been recognized as a potential and preventable problem for decades but it remains so even today.[21] Train of four ratio <0.9 has been defined as an RNMB. The presence of residual paralysis is documented in the postoperative period even with the use of intermediate-acting neuromuscular blocking agents and reversal of its action. Routinely used anticholinesterase drugs are found to be ineffective in reversing profound and deep levels of neuromuscular block, whereas on the other side of the recovery curve administration of anticholinesterases close to full recovery may induce paradoxical muscle weakness. In 1997, Eriksson et al. used video radiography and computerized pharyngeal manometry for evaluation of pharyngeal function in a partial neuromuscular blockade and demonstrated that the effects of neuromuscular blockade lead to an increased risk of pulmonary inhalation.[22] Sundman et al. in 2000 described a four- to five-fold increase in the pharyngeal dysfunction causing misdirected swallowing with a TOFR of 0.9 or less.[23] Eikermann et al. in 2007 observed an increased risk of severe postoperative pulmonary complications such as upper airway collapsibility with TOFR <0.8.[24] In 2009, Herbstreit et al. described that at minimal neuromuscular blockade (TOFR 0.5–1) incidence of upper airway collapsibility increased and impairs upper airway dilator muscle compensatory responses to negative pharyngeal pressure challenges.[25] In 2016, Fuchs-Buder et al. described marked impairment of inspiratory flow to around 50% of baseline with TOFR of 0.5, and even at a TOFR of 0.8 upper airway dysfunction persisted and manifested as impaired ability to swallow, diminished upper airway volume, decreased peak inspiratory flow, and impaired function of the genioglossus muscle.[14] Murphy and Brull in 2010 had demonstrated impaired pharyngeal function and increased risk of aspiration, weakness of upper airway muscles and airway obstruction, unpleasant symptoms of muscle weakness, and attenuation of the hypoxic ventilator response in volunteers even with a minimal degree of residual paralysis (TOFR 0.7–0.9).[26] Saager et al. demonstrated that residual neuromuscular block in the post-op period was associated with respiratory and other complications such as difficulty in breathing and swallowing, hypoxia, hypercapnia, slurred speech, blurred vision, and delayed clinical recovery.[27]

In summary, some of the effects of the RNMB are swallowing dysfunction, upper esophageal sphincter relaxation, increased risk of aspiration, decreased inspiratory airflow, reduction in the upper airway volume, impaired ventilatory response to hypoxia, and profound lethargy.

Prevention or Overcome

In our day-to-day practice, routine NMM is not being done and we use standard doses of neostigmine (50 μg/kg) as a reversal of neuromuscular blockers when the patient attempts breathing as a clinical sign of the early stage of recovery from neuromuscular blocking effects and also extubate based on the clinical sign such as sustained head lift for >5 seconds. However, the correlation between the clinical features and TOFR in NMM is variable. Recovery of neuromuscular blockade depends on the age and weight of the patient, interval between the last dose of neuromuscular blocker and reversal agent, depth of neuromuscular blockade, and dosage of the reversal agent. Attempts of spontaneous breathing indicate partial recovery of neuromuscular blockade and administration of reversal agent shall potentiate the neuromuscular recovery and maintaining nil per oral status for at least 2 hours are the safety conditions which had prevented micro-aspiration and desaturation. Many authors had demonstrated and concluded that NMM devices allow for accurate titration and rational use of the neuromuscular blocking agents and thus the incidence of residual neuromuscular block can be reduced.[4,26,28] Raval et al. suggested few preventive strategies to prevent RNMB namely to analyze the need for NMBDs, monitor the depth of blockade, and avoidance of long-acting NMBAs.[29] Adequate neuromuscular recovery assessed by increasing number of TOF twitches before reversal correlates with a reduced prevalence and severity of residual paralysis, and a decreased incidence of postoperative pulmonary complications such as atelectasis and pneumonia.[30]

Conclusion

Either to prevent or to overcome the ill effects of the RNMB routine NMM has to be followed whenever neuromuscular blockers are used.

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