Earn CME/CE
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Clinical UPDATE

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ESTIMATED TIME TO COMPLETE ACTIVITY: 1.0 hour

TARGET AUDIENCE

This activity is intended for anesthesiologists and certified registered nurse anesthetists engaged in the care of patients with residual neuromuscular blockade (rNMB).

EDUCATIONAL OBJECTIVES

After completing this activity, the participant should be better able to:

- Identify risk factors for rNMB that should be considered when selecting patients for ambulatory surgery
- Compare the efficacy and safety of neuromuscular blockade reversal strategies used in ambulatory surgery
- Integrate strategies for prevention of rNMB into care for patients in the ambulatory surgery setting
- Design effective interdisciplinary communication strategies to improve postsurgical patient handoffs

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Mr Lando has nothing to disclose.

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Vijay Patel, MD, has nothing to disclose.

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Case Discussions on Improving Outcomes of Ambulatory Surgery: Neuromuscular Blockade and Its Reversal

Introduction

The expanding scope of ambulatory surgical procedures and the increasingly common use of deep blockade with intermediate-acting neuromuscular blocking agents (NMBAs) for short procedures has the potential to lead to more cases of residual paralysis, a potentially fatal complication of surgery requiring hospital admission in many cases.[1-3] Detection and management of residual neuromuscular blockade (rNMB) at the conclusion of surgery can be challenging in the ambulatory surgery setting for a variety of reasons. A lack of neuromuscular blockade (NMB) monitoring equipment, a variation in the availability of reversal agents, restricted business hours, a lack of equipment and staff capable of managing adverse respiratory events, and pressure to maintain a high rate of turnover all threaten optimal patient outcomes.

The importance of NMB monitoring and reversal cannot be understated. Due to the potential for serious adverse effects resulting from rNMB, monitoring and adequate reversal of NMB have recently been included in enhanced recovery recommendations.[4] Adequate reversal can also improve measures of patient satisfaction and resultant reimbursement. In this activity, experts in the field of ambulatory surgery who currently practice in standalone ambulatory surgery centers will discuss the unique challenges associated with management of NMB in the ambulatory surgical setting. In addition, they will talk about how these challenges can be overcome through appropriate patient selection, enhanced staff communication, and NMB monitoring and reversal strategies.

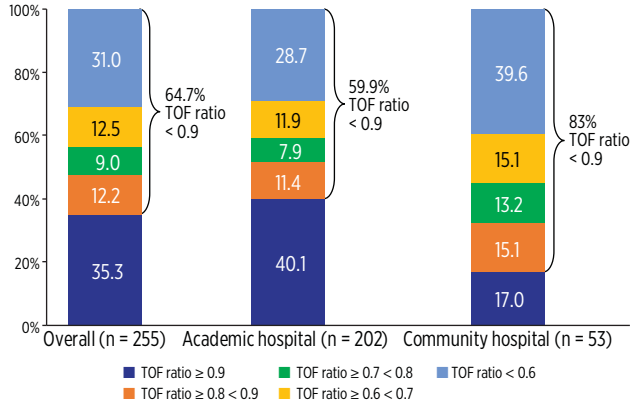

Figure 1. Incidence of residual neuromuscular blockade in different settings in the RECITE-US study[7]

Abbreviations: RECITE, Residual Curarization and Its Incidence at Tracheal Extubation; TOF, train-of-four.

Reprinted from *Journal of Clinical Anesthesia*, 55, Saager L, Maiese EM, Bash LD, et al, Incidence, risk factors, and consequences of residual neuromuscular block in the United States: the prospective, observational, multicenter RECITE-US study, 33-41, Copyright 2019, with permission from Elsevier.

Incidence of Residual Neuromuscular Blockade

Prior to 2015, the incidence of rNMB was estimated to be approximately 40%, according to a number of studies using various quantitative and qualitative methods of measuring recovery.[3] The multicenter Canadian RECITE (Residual Curarization and Its Incidence at Tracheal Extubation) study (N = 302) revealed an incidence of 63.5% at extubation and 56.5% at arrival in the postanesthesia care unit (PACU) based on quantitative acceleromyography, with rNMB defined as a train-of-four (TOF) ratio (TOFr) of < 0.9.[5,6] The recent multicenter RECITE-US study (N = 328) confirmed this finding. At extubation, 64.7% of the study population had a TOFr of < 0.9 and 31.0% had a TOFr of < 0.6, despite administration of neostigmine and qualitative assessment of recovery from NMB **(Figure 1)**.[7] Higher body mass index (BMI), male sex, a shorter duration of surgical procedure, and a shorter time from reversal to extubation were all significantly associated with a higher incidence of rNMB. These variables—particularly the shorter durations of surgical procedure and time from reversal to extubation—could help explain the higher incidence of rNMB (83%) observed in the community hospital setting, where operating room (OR) time constraints and high patient turnover are likely.

Consequence of Residual Neuromuscular Blockade

Unplanned Hospital Admission

Unplanned hospital admissions/readmissions following surgery are an ongoing challenge for health care systems.[8] Among surgical patients, the risk of 30-day readmission is significantly higher for patients undergoing ambulatory surgery and those receiving higher doses of NMBA and/or neostigmine.[8] The drivers of this phenomenon are unclear, but undetected rNMB leading to respiratory impairment could play a role.[8] A 2017 Agency for Healthcare Research and Quality ambulatory surgery safety report indicated that airway management/concerns were the second most commonly cited reason for unexpected hospitalization, following unstable vital signs.[9] This finding supports a role for rNMB as a driver of hospital admissions following ambulatory surgery. The muscles that control pharyngeal and respiratory function are weakened during NMB, even at minimal levels of blockade. Several studies demonstrate that even at a TOFr of 0.7 to 0.9, persons receiving NMB experience impaired airway protective reflexes, upper airway obstruction, decreased hypoxic ventilatory response, and postoperative hypoxemia.[10-13] Adverse respiratory events, including persistent atelectasis and aspiration pneumonitis, have been associated with increased morbidity and mortality among patients who develop one or more following major surgery.[14]

Patient Satisfaction

Patient-centered outcomes have become a focus of health care quality improvement, as measured by the Centers for Medicare & Medicaid Services, and will soon be tied to reimbursement.[15] Postsurgical symptoms—specifically, sore throat, nausea, and vomiting—are important correlates

of patient satisfaction with anesthesia following ambulatory surgery.[16-18] The risk for tracheal injury precipitating sore throat and/or hoarseness increases with each intubation. Therefore, adequate NMB reversal should reduce this risk and others associated with reintubation. The risk of postoperative nausea and vomiting can be minimized in several ways, including selection of an appropriate reversal agent.[4,19]

Economic Considerations

The overall cost of *1 minute* in the OR has been estimated at between $22 and $133.[20] If rNMB is not reversed or inadequately reversed, causing OR clinicians to delay extubation, the costs for the facility can increase dramatically. The total cost of care can also skyrocket if rNMB leads to unplanned hospital admission. The cost savings associated with avoiding intensive care unit admission due to rNMB is, on average, €1355 (approximately $1500) per ICU day.[21] With appropriate reversal, the risk of these costs being caused by rNMB can be reduced or eliminated.

Best Practices in Preventing Blockade in the Ambulatory Surgery Setting

Risk Assessment

Assessing and identifying risk factors for rNMB and the importance of NMBA choice and reversal strategy are both critical for improving surgical patient outcomes. rNMB preferentially affects respiration; thus, preexisting pulmonary disease can increase the risk for rNMB.[22] Other patient-specific factors that can increase the risk for rNMB and respiratory complications include:

- Obesity[23]
- Age > 70 years[24,25]
- Myasthenia gravis[26]
- Obstructive sleep apnea[27]
- Renal failure[28]
- Type 2 diabetes mellitus[29]

Q: How do you tailor patient selection criteria for ambulatory surgery on the basis of risks for rNMB?

Mr Lando: Our challenge in ambulatory surgery is to balance effective anesthesia with rapid recovery. We must select patients who we have reason to believe will not require excessive NMB and who are likely to recover well. To that end, one of our strictest criteria involves BMI. The type and duration of surgery and whether NMB redosing is anticipated are also considerations. In addition, patients' pulmonary comorbidities and anticipated intraoperative ventilatory requirements factor in patient-selection decisions for the ambulatory surgery center. We try to limit the American Society of Anesthesiologists score to 3.

Dr Choice: At Montefiore Medical Center, we use a stratified patient-selection algorithm consisting of absolute contraindications to ambulatory surgery (eg, a BMI ≥ 50 kg/m^2 requiring more than minimal sedation), and other factors that we believe need a more nuanced approach (eg, aged ≥ 80 years) **(Table 1)**.

Dr Guertin: We also consider BMI and pulmonary disease to be major considerations because both have been shown to increase the risk for rNMB.[7,22] Severely compromised kidney function and musculoskeletal disorders such as multiple sclerosis also factor into our criteria.

Table 1. An Example of an Abbreviated Patient-Selection Algorithm for Ambulatory Surgery

Montefiore Hutchinson Ambulatory Surgery Center Patient Selection Criteria*†

Anticipated duration of surgery should be ≤ 4 h with anticipated blood loss ≤ 300 mL

ABSOLUTE Contraindication	CONSULTATIVE Consideration
Pulmonary	
Postoperative mechanical ventilation or ventilatory support	Home oxygen use
Organ Failure	
End-stage renal disease requiring more than minimal sedation	CKD 4 or 5
	Cirrhosis with decreased liver function or ascites
	Bleeding/Coagulation disorders/ Anticoagulation (besides aspirin)
Age	
< 14 years	≥ 80 years
Morbid Obesity/Airway Concerns	
BMI ≥ 60 kg/m²	BMI ≥ 40 kg/m²
BMI ≥ 50 kg/m² requiring more than minimal sedation	History of difficult airway or intubation
	Craniofacial abnormalities
Severe OSA requiring postoperative opioids	Patients with OSA
C-spine precautions (neck collar or halo)	History of cervical spine surgery, T-spine or L-spine precautions
Miscellaneous	
Acutely intoxicated from drugs or alcohol	History of epilepsy (seizure disorder) or focal neurologic deficit
Cocaine use < 24 h	Pregnancy
	Severe cognitive dysfunction/ Behavioral issues
	Buprenorphine/naloxone or methadone maintenance
	History of anesthetic complication: Malignant hyperthermia, myasthenia gravis, pseudocholinesterase deficiency, etc

Note: Patient-specific factors that heighten the risk for residual neuromuscular blockade are highlighted in dark blue.

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CKD, chronic kidney disease; ECG, electrocardiogram; OSA, obstructive sleep apnea.

* **ECG criteria:** If a patient has 1 clinical risk factor for coronary disease (eg, history of ischemic heart disease, compensated heart failure, cerebrovascular disease, CKD, or diabetes mellitus). Exception for diabetes: adult with type 1 diabetes aged < 30 years. May use ECG from within last 6 months unless patient has new or active symptoms from last ECG. Please have old ECG to compare data.

† **Preoperative medical assessment forms:** Required for ASA 3 or BMI ≥ 40 kg/m^2 patients for intermediate surgical risk procedures.

Table courtesy of Curtis Choice, MD/Montefiore Hutchinson Ambulatory Surgery Center.

Monitoring Recovery From Neuromuscular Blockade

In an effort to address the high rate of rNMB observed in recent studies, an expert consensus panel was convened to define best practices in monitoring NMB.[30] Key recommendations from the panel include using quantitative monitoring whenever possible and abandoning use of subjective tests of recovery from NMB (eg, visual or tactile assessment of "fade" with peripheral nerve stimulation or assessment of clinical signs, such as 5-second head lift, sustained handgrip, and spontaneous respiration). Clinical tests are unreliable indicators of recovery from NMB, as indicated by a body of research demonstrating a lack of correlation between clinical signs/tests and TOFr > 0.9.[30-33] Several studies have shown that at a TOFr > 0.4, even experienced anesthesiologists cannot reliably detect fade by tactile or visual (subjective) assessment.[34-37] The panel also recognized that access to quantitative monitoring can be limited and recommended mandatory use of a peripheral nerve stimulator (PNS) in these instances. **Table 2** reviews current methodologies to provide a clinically relevant framework for selecting a quantitative monitor when the opportunity arises.[30,38-42]

Q: What is your facility's strategy for monitoring NMB?

Dr Choice: At this time, Montefiore's standalone ambulatory-surgery centers do not have quantitative monitors. We use a PNS to perform TOF stimulation to quantify the number of twitches and estimate fade during recovery.

Dr Guertin: At our ambulatory-surgery center in Ohio, we have recently acquired a quantitative monitoring system based on kinemyography. We have had good uptake among providers, who report ease of use and reliable readings that have enabled informed decisions regarding extubation and transfer to the PACU. Interestingly, we recently had one of our first cases using the quantitative monitor. At the end of the case, the patient had a full 4/4 twitches, with no visually discernible fade, but the monitor indicated 0.4 when I would have expected 0.9. We administered sugammadex; 2 minutes later, TOFr was 0.89.

Q: In lieu of quantitative monitoring, what do you recommend to assess extubation readiness?

Mr Lando: Without relying on clinical tests, I think our only option is TOF monitoring.

Dr Choice: I think the first step would be to minimize use of NMB. In several cases, you do not have a choice. In those scenarios, TOF must be used, ideally in conjunction with a reversal agent.

Dr Guertin: In the absence of quantitative TOF monitoring, the use of qualitative monitoring combined with clinical signs, such as head lift and negative inspiratory force, are the only alternatives when NMB is required. However, careful titration of NMB, adequate time to assess reversal, and vigilant clinical assessment are absolutely necessary.

Reversal of Neuromuscular Blockade

Three main strategies can be considered for reversing NMB following the conclusion of surgery: (1) waiting for spontaneous recovery, (2) administering a cholinesterase inhibitor such as neostigmine in conjunction with an antimuscarinic agent, and (3) administering sugammadex. Giving sugammadex as a "rescue" strategy following administration of neostigmine is an alternative approach.[21] In this section, the strengths and limitations of each approach will be discussed in the context of the unique challenges faced in ambulatory surgery.

Residual Neuromuscular Blockade and Complications

Data on the rate of rNMB among patients allowed to spontaneously recover from NMB without reversal are limited and varied, but suggest

Table 2. Objective TOFr Monitoring Methodologies[30,38-42]

Method	Measurement	Advantages	Limitations
Mechanomyography	Force transducer measures isometric muscle contraction	• Precision and repeatability	• None currently commercially available • Requires fixed-arm positioning and preloading
Electromyography	Area under the curve or amplitude of evoked muscle action potential	• Does not require immobilization of monitored arm • Can be used at sites other than the arm	• Freestanding device recently FDA cleared
Acceleromyography	Piezoelectric ceramic wafer detects acceleration, which is converted to an electric signal that is proportional to force of muscle contraction	• Several units available commercially • Newer 3-dimensional units are easier to calibrate	• Several commercially available devices • Requires a freely moving thumb, with current FDA models requiring specific vector movement for calculation • Baseline TOFr can exceed 1.0, leading to erroneous results • Most commercially available units are not validated against gold standards
Kinemyography	Piezoelectric-material deformation causes a measurable electric signal proportional to force	• Repeatable measurements • Results correlate with those of mechanomyography	• Requires a freely moving thumb

Abbreviations: FDA, US Food and Drug Administration; TOFr, train-of-four ratio.

that even waiting 20 to 30 minutes prior to extubating only avoids approximately one-half of rNMB cases.[43] Among more recent studies that have attempted to quantify the incidence of rNMB at extubation or PACU admission, some (most notably the RECITE studies) have included patients who were given neostigmine and then extubated when subjective criteria were met.[5,7] Similar studies have also been conducted with sugammadex alone[44] or comparing the rate of rNMB at extubation with neostigmine and sugammadex.[45-48] An important limitation of both reversal strategies is that recovery to TOFr ≥ 0.9 is not guaranteed with use. RECITE-US suggested that neither the use of neostigmine nor PNS predicted recovery to TOFr ≥ 0.9, reinforcing the idea that better reversal strategies are needed.[7] Ideally, quantitative monitoring should be used in conjunction with reversal to ensure adequate recovery prior to extubation. Because such monitoring is not always possible, careful consideration of the risk for rNMB associated with each agent is important. A 2016 meta-analysis of 13 randomized, controlled trials (RCTs) compared neostigmine and sugammadex for reversal of moderate or deep blockade induced with rocuronium or vecuronium.[19] The incidence of rNMB (as defined as TOFr < 0.9 at extubation) was compared across 4 studies. Compared with neostigmine, sugammadex was associated with a significantly lower risk for rNMB (odds ratio 0.05; 95% confidence interval, 0.01-0.43; *P* = .0068). Giving sugammadex either as first-line or rescue treatment following neostigmine has also been associated with lower incidences of respiratory adverse events (AEs), unplanned ICU admissions related to rNMB, and 30-day readmissions.[21,49]

Time to Recovery

The meta-analysis of RCTs, in which moderate blockade was used, also demonstrated a significantly shorter time to recovery to TOFr ≥ 0.9 when sugammadex was used, as compared with neostigmine (*P* < .0001) **(Figure 2)**.[19]

A 2017 Cochrane review of RCTs came to a similar conclusion, with faster NMB recovery using sugammadex.[50] Comparing 2 mg/kg of sugammadex with 0.05 mg/kg of neostigmine to reverse rocuronium-induced moderate NMB, sugammadex was 6.6 times faster than neostigmine (1.96 vs 12.87 minutes, respectively) when reversing at the appearance of the second twitch. When reversing from posttetanic count of 1 to 5, 4 mg/kg of sugammadex was 16.8 times faster than 0.07 mg/kg of neostigmine (2.9 vs 48.8 minutes, respectively). The use of sugammadex as a rescue strategy following neostigmine administration does not result in a reduction in the time spent in the OR vs preventative sugammadex, possibly due to the time needed to determine that rescue is required.[21] With sugammadex, estimates are that 14 minutes of OR time per procedure would be saved compared with neostigmine when TOFr ≥ 0.9 is confirmed prior to extubation.[51]

Nonrespiratory Adverse Events

Although spontaneous recovery avoids AEs associated with NMB reversal agents, both neostigmine and sugammadex have important safety considerations. Neostigmine is associated with AEs such as bradycardia, nausea and vomiting, and bronchospasm.[52] Sugammadex is associated with bradycardia, vomiting, pain, nausea, hypotension, and

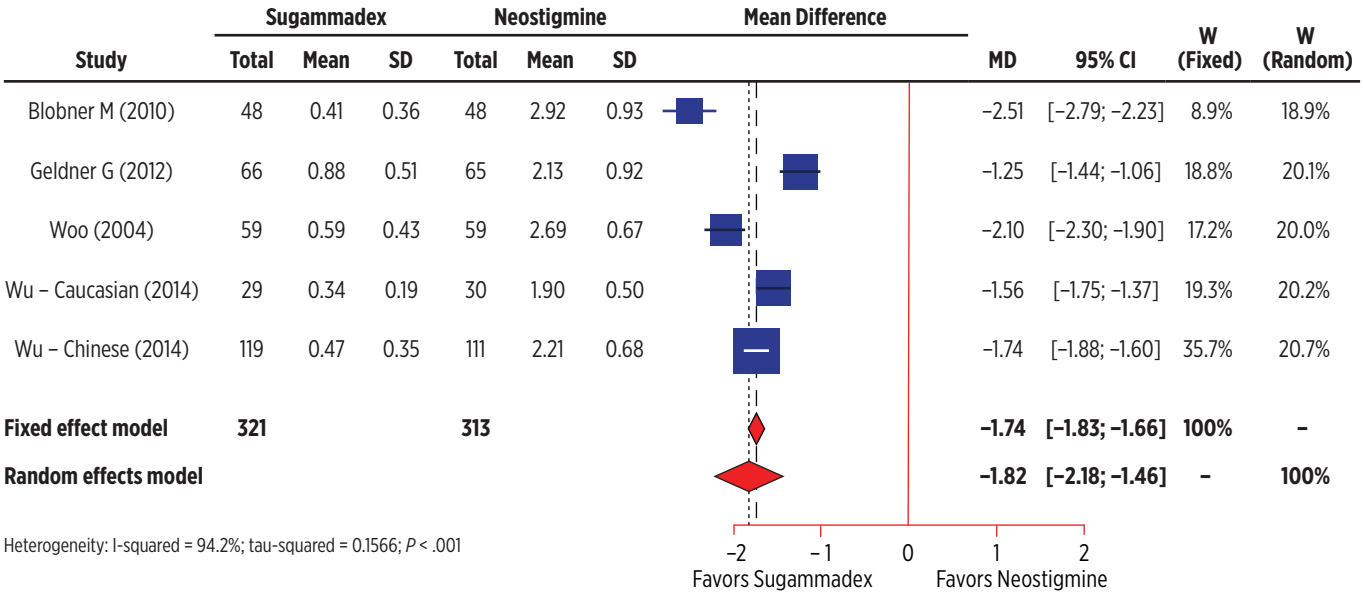

Figure 2. Meta-analysis of time to recovery to train-of-four ratio ≥ 0.9 using either sugammadex or neostigmine to reverse moderate rocuronium-induced neuromuscular blockade[19]

Abbreviations: CI, confidence interval; MD, mean difference; SD, standard deviation.

Reprinted from *Journal of Clinical Anesthesia*, 35, Carron M, Zarantonello F, Tellaroli P, Ori C, Efficacy and safety of sugammadex compared to neostigmine for reversal of neuromuscular blockade: a meta-analysis of randomized controlled trials, 1-12, Copyright 2016, with permission from Elsevier.

Table 3. Dosing Recommendations for NMB Reversal Agents

NMB Reversal Agent	Dosing and Administration
Neostigmine	• 0.03 mg/kg for reversal of NMBAs with shorter half-lives (eg, mivacurium)[52] – When third to fourth twitch response to TOF stimulation is present (TOFc of 3 to 4) or when first twitch response is substantially greater than 10% of baseline[6,52,55,56]
	• 0.07 mg/kg (up to 5 mg) is the maximum recommended dose[52]
	• 0.07 mg/kg for reversal of intermediate-acting NMBAs (eg, rocuronium and vecuronium)[52] – When second twitch response is present or when first twitch response to TOF stimulation is close to 10% of baseline[52]
Sugammadex	• 2 mg/kg for reversal of rocuronium and vecuronium when second twitch response to TOF stimulation reappears[53]
	• 4 mg/kg for reversal of rocuronium and vecuronium when there are no TOF twitch responses, but there is a PTC of at least 1[53]
	• 16 mg/kg when there is a clinical need to reverse NMB immediately after the administration of rocuronium[53]

Abbreviations: NMB, neuromuscular blockade; NMBA, neuromuscular blocking agent; PTC, posttetanic count; TOF, train-of-four; TOFc, train-of-four count.

Table 4. PATIENT Mnemonic to Guide a Standardized Postanesthesia Care Unit Handoff[60,61]

P	Patient (quick scan): Preoperative assessment and current condition Position Pacemaker
A	Anesthesia: Type of anesthetic/medications Antibiotic Airway: Level of difficulty and current management Allergies
T	Temperature: Includes type of monitoring and warming devices
I	Intravenous/invasive lines: Type of access, infusions, blood products, intakes, and outputs
E	End-tidal carbon dioxide: Vent parameters, respiratory rate, peak inspiratory pressure, O_2 level, and vent mode
N	Narcotics: Those given and those needing to be reconciled
T	Twitches: Neuromuscular monitoring and degree of paralysis "Did the patient get reversal?" "How many twitches did the patient have prior to reversal?" "What was the patient's train-of-four ratio when extubated?"

headache.[53] Patients should be advised that sugammadex can bind to progesterone, which might nullify the effect of hormonal contraceptives. Overall, a meta-analysis demonstrated that sugammadex is associated with a lower incidence of respiratory and cardiac AEs compared with neostigmine, but a similar rate of neurologic AEs.[19] Sugammadex is also associated with a lower rate of postoperative nausea and vomiting, which could translate to better patient satisfaction.[50,54]

Dosing Considerations

Dosing strategies for neostigmine and sugammadex that consider various depths of NMB are well-defined **(Table 3)**.[6,52,53,55,56] Best practices are less clear for obese patients, in whom dosing of anesthetic drugs is often based on ideal weight.[57] The maximum dose of neostigmine is 5 mg, regardless of weight.[52] Thus, the potential for increased risk for rNMB exists in patients who are morbidly obese. Sugammadex is renally cleared. In those with mild or moderate renal impairment, no dosage adjustment is necessary, but use in patients with severe renal impairment is not recommended.[53] Another important limitation of sugammadex is that the agent can only bind to and reverse blockade induced with rocuronium or vecuronium.

In an effort to identify cost-saving measures, several groups have investigated whether reducing the dose of sugammadex to half the label recommendation is still effective. Although 1 group found that combination reversal with 2 mg/kg of sugammadex and 0.05 mg/kg of neostigmine was nearly as effective as 4 mg/mL of sugammadex alone for reversing deep blockade, others cautioned that this practice has led to transient recovery of TOFr, with subsequent recurarization.[58] This can put patients at an increased risk for complications of rNMB that only manifest in the PACU or worse, after discharge home.

Enhancing Communication at Handoff

Adverse respiratory events can manifest in the PACU that are likely related to rNMB, but not recognized as such at the time of handoff.[59] To increase the effectiveness and efficiency of handoff communications, the PATIENT mnemonic was devised **(Table 4)**.[60,61] This set of criteria can be used as part of a paper or electronic-handoff checklist, addressing the recent Centers for Medicare & Medicaid Services and American Medical Association published quality measures related to postanesthetic transfer of care to the PACU that supports the use of standardized checklists or protocols.[62,63]

Case Discussions

In this section, 2 cases will illustrate the presentation and consequences of rNMB in the ambulatory setting. Faculty discussion regarding best practices to avoid such scenarios and additional clinical pearls for the ambulatory surgical practice follow each case presentation.

Case 1: A Case of Mistaken Recovery

From the Files of Michael Guertin, MD, MBA, CPE, FASA

A 16-year-old, healthy male wrestler underwent tympanoplasty in a free-standing, off-campus ambulatory surgery center affiliated with Ohio State University.

He received standard induction with:

- 200 mg of propofol
- 50 mg of rocuronium
- 100 μg of fentanyl
- Maintenance on desflurane

The surgery lasted approximately 60 minutes, at the end of which he received 0.04 mg/kg of neostigmine and glycopyrrolate. Sugammadex was not available at this time. After approximately 10 minutes, he had recovered 4/4 qualitative TOF counts at the ulnar nerve/adductor pollicis. He also opened his eyes, was able to maintain a purposeful handgrip, and began to fight with the endotracheal tube. The patient was extubated, but he began to struggle with discoordinated movement, became agitated, and likely developed laryngospasm with peripheral capillary oxygen saturation (SpO_2) of 85%. He was combative, which contributed to an inability to relieve the laryngospasm with positive pressure via mask, and was then reintubated after an adequate dose of propofol and 100 mg of succinylcholine. After reintubation, pink, frothy material was immediately evident in the endotracheal tube. His SpO_2 recovered to > 90%, and he was allowed to spontaneously recover. After 20 minutes, the patient's TOF count was confirmed at 4/4, and extubation was attempted again successfully. After several hours in the PACU, he was transferred to the hospital in an ambulance for overnight observation of presumed negative pressure pulmonary edema. He was discharged the next morning without any further complications.

Case 1 Commentary

Mr Lando: Given this scenario and in lieu of quantitative monitoring, it seems like any anesthesia provider would think that the patient was ready to be extubated.

Dr Choice: I agree. This case illustrates a common phenomenon, wherein patients in this age group can emerge from anesthesia unpredictably, sometimes displaying purposeful movements that might not necessarily indicate full recovery from NMB.

Dr Guertin: Because we only had qualitative TOF monitoring, it is very possible that he had rNMB or paradoxical weakness sometimes observed when neostigmine is given when the TOF count is 4/4.[64] In this young, very muscular and anxious patient, that weakness with discoordinated movement suggestive of partial paralysis might have led to his initial agitation and increased his risk of laryngospasm. Given that sugammadex reverses NMB within 1 to 3 minutes, on average,[50] it would have fully reversed his NMB before he began opening his eyes and moving around, thus reducing his agitation and anxiety. This might have reduced his risk of subsequently developing laryngospasm.

Case 1 Take-Home Points

- Clinical signs indicating recovery from NMB can be misleading
- Even when a patient has a TOF count of 4/4 after reversal with neostigmine, full recovery might not occur until 10 to 40 minutes later, depending on the depth of block
- rNMB can lead to pulmonary complications necessitating transfer from the ambulatory surgery center to the hospital for overnight monitoring

Case 2: Slow Recovery in a Patient With Well-Controlled Asthma

From the Files of Stan Lando, CRNA, and Curtis Choice, MD

A 38-year-old female underwent a laparoscopic ovarian cystectomy and lysis of adhesions. Her BMI was 42 kg/m^2, and she had a history of mild, intermittent asthma controlled with occasional inhaler use. Her last use of the inhaler was 2 weeks before surgery, when she had an upper respiratory infection. Her previous anesthetic history was uneventful. She received routine induction with:

- 2 mg of midazolam
- 100 μg of fentanyl
- 100 mg of lidocaine
- 250 mg of propofol
- 50 mg of rocuronium
- Sevoflurane for maintenance

Endotracheal intubation was easy and atraumatic. The patient was placed in Trendelenburg positioning. After 30 minutes, an increase in peak airway pressures began to appear. Correct positioning of the endotracheal tube was confirmed, suctioning was performed, and bilateral breath sounds auscultated. An additional 200 μg of fentanyl and 30 mg of rocuronium were given throughout the case to offset difficulty that the surgeon experienced with surgical exposure from decreased insufflation pressures. During this time, peripheral nerve stimulation revealed only posttetanic twitches or 1/4 TOF twitches.

The procedure lasted approximately 2.5 hours. At the conclusion of the procedure, the patient was given 5 mg of neostigmine and glycopyrrolate to reverse NMB. Train-of-four stimulation yielded 1/4 twitches at the time of reversal. Soon after reversal, she developed bronchospasm, as demonstrated by high peak airway pressures, bilateral wheezing, and SpO_2 desaturation to 85%. Three puffs of albuterol were given in the endotracheal tube, which resolved the bronchospasm and associated O_2 desaturation within a few minutes. Twenty-five minutes after neostigmine administration, she regained 4/4 twitches, with minimal tactile fade, and began to meet extubation criteria. Following extubation, the patient exhibited dyspnea and increased work of breathing. Her SpO_2 decreased to 93%, prompting placement of a nasal trumpet and airway support with 2-person positive ventilation by mask. Ventilatory support and monitoring continued in the OR for another 45 minutes until clinical extubation criteria along with a TOF count of 4/4 without fade were achieved. She was then transferred to the PACU, where she recovered uneventfully for another 4 hours until discharge home.

Case 2 Commentary

Dr Guertin: This case illustrates a common scenario in which respiratory complications can arise following surgery. The patient had 2 common yet important risk factors for rNMB and complications: obesity and asthma. How her asthma, obesity, and the deep level of NMB each contributed to her postoperative experience is uncertain, but it is clear that the consequences included significant pulmonary complications, extended OR time, and extended PACU recovery time.

Mr Lando: It is likely that her positioning during surgery and administration of neostigmine also played a role. Sugammadex was not yet available at the time of this case; thus, we had to give the maximal dose of neostigmine, which the patient could not tolerate.

Dr Choice: Having sugammadex available now has given anesthesia providers the confidence to induce a deep blockade to facilitate these types of challenging laparoscopic procedures, armed with the knowledge that they can expect a faster, more complete recovery.

Mr Lando: If we had administered sugammadex, we might have been able to send her out to the PACU sooner, perhaps with an albuterol nebulizer. That way, we would have felt more comfortable knowing that she was more likely to be fully reversed.

Case 2 Take-Home Points

- Clinical parameters are inferior to neuromuscular monitoring to determine extubation readiness
- Quantitative monitoring is superior to qualitative monitoring in determining the level of NMB reversal
- Neostigmine (given with anticholinergic agents) has the potential to exacerbate reactive airway disease. Sugammadex is indicated for patients at risk of experiencing this complication.
- Sugammadex reversal allows for deeper NMB because unlike neostigmine, this agent does not require some return of spontaneous recovery to be effective

Conclusion

The advent of quantitative monitoring has brought to light the high incidence of rNMB, which places patients at risk for postsurgical pulmonary complications and puts a financial burden on ambulatory surgery centers. To mitigate these risks, patients must be carefully selected according to individual risk for rNMB and complications. Quantitative monitoring should ideally be used to ensure that each patient achieves a TOFr $\geq$ 0.9 prior to extubation. When this technology is not available, though, TOF stimulation coupled with adequate reversal must be used. Neostigmine and sugammadex each have important safety and efficacy considerations. Overall, sugammadex has a better efficacy and safety profile, as shown in several head-to-head studies. Finally, even when monitoring and reversal have been used, pulmonary complications of rNMB can manifest after an initial recovery period, highlighting the importance of thorough communication during the handoff process.

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