Arab Republic of Egypt
Egyptian Health Council
Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management

Guideline for
Monitoring and Antagonism of Neuromuscular Blockade

Prepared by

The "Guidelines Development Group" (GDG) of the Scientific Committee of the Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management.

Contents

Acknowledgements

The Guideline for Monitoring and Antagonism of Neuromuscular Blockade - was prepared by the ***Guidelines Development Group (GDG)*** *of the Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management group which reserves the right to determine the publication and distribution of the Guidelines. The Guideline is subject to revision, and the updated versions will be published when needed, as warranted by the evolution of new-evidenced medical knowledge, new technology, and new practice trends. Although the Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management encourages Egyptian anesthesiologists to adhere to its practice guidelines to ensure high-quality patient care, we cannot guarantee any specific patient outcome. With recognition that successful implementation requires coordinated approaches that align protocols with objectives at the institutional level, anesthesiologists should exercise their own professional judgement in determining the proper course of action for any patient's circumstances. Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management assumes no responsibility or liability for any error or omission arising from the use of any information contained in its Guideline to the Practice of Monitoring and Antagonism of Neuromuscular Blockade.*

This Guideline is intended to apply to all anesthesiologists in Egypt. *The independent practice of anesthesia is a specialized field of medicine, which should be practiced by physicians with appropriate training who continue their education in the practice of anesthetics, surgical intensive care, pain management, perioperative care, and resuscitation.*
All physicians applying for privileges in anesthesia should show satisfactory completion of specialist postgraduate training in anesthesiology certified by either the Egyptian Board training or the standard training in University programs to be able to provide these services. International medical graduates approved for licensure by provincial regulatory bodies should show training equivalent to the Egyptian standard. The only route to specialist recognition in anesthesiology in Egypt is through the "certification process" of the "Egyptian Health Council" (EHC).

We would like to acknowledge the important contributions to the guideline from members of the Anesthesia ***Guidelines Development Group (GDG)*** *of the Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management.*

Development Committee for adapting these guidelines

Chair of the GDG:
Prof. Sanaa Abd El-Kareem Helmy, Head of the Scientific Council of the Egyptian Board of Anesthetics, Surgical Intensive Care and Pain Management. Prof. of Anesthesia, Intensive Care and Pain Management, Faculty of Medicine, Cairo University.
Rapporteur of the GDG:
Prof. Salah El-Sherif, Prof. of Anesthesia, Intensive Care and Pain Management, Faculty of Medicine, Tanta University.
Members of the GDG are professors of Anesthetics, Intensive Care and Pain Management :
- Prof. Hassan Mohamed, Faculty of Medicine, Cairo University.
- Prof. Hala El-Gendy, Faculty of Medicine, Tanta University.
- Prof. Ghada Ali, Faculty of Medicine, Menofia University.
- Prof. Khaled Maghawry, Faculty of Medicine, Ain Shams University.

Abbreviations

AGREE II: Appraisal of Guidelines for Research and Evaluation II
ASA: American Society of Anesthesiologists
CI: Confidence Interval
DBS: Double Burst Stimulation
EHC: Egyptian Health Council
ESAIC: European Society of Anaesthesiology and Intensive Care
FDA: Food and Drug Administration**.**
GDG: Guidelines Development Group
GRADE: Grading of Recommendations, Assessment, Development and Evaluation
NM: Neuromuscular
NMB: Neuromuscular blockade
NMBAs: Neuromuscular blocking agents
PACU: Post-anesthesia Care Unit
PTC: Post-Tetanic Count
RCTs: Randomized Controlled Trials
RNMB: Residual Neuromuscular Blockade
TOF: Train-of-Four
WHO: World Health Organization

Glossary

Basic Principles and Terminology

The following definitions are used For the purposes of this guideline:

Clinical assessment of recovery from neuromuscular blockade**:** using "clinical" assessments of paralysis, *e.g.*, sustained head lift, grip strength or respiratory measurements.

Double Burst Stimulation (DBS): Two short bursts of tetanic stimuli used to make visual/tactile fade easier to spot when electronic tools are limited.

Normalization of train-of-four ratios to the baseline (control): value obtained before neuromuscular block is accomplished by dividing the postoperative measurements by the baseline value.

Post-Tetanic Count (PTC): Used for intense blocks when TOF shows 0 twitches. A 50 Hz stimulus is given followed by single twitches to gauge how close the patient is to returning to a measurable TOF.

Qualitative assessment: using peripheral nerve stimulators (which could deliver a single stimulus and sometimes a tetanic stimulus).

Quantitative monitoring: amplitude of the twitches can be measured quantitatively to permit the calculation of the *train-of-four ratio.*

Train-of-Four (TOF): The gold-standard test delivering 4 rapid impulses at 2 Hz. It tracks "fade," measuring the ratio of the 4th twitch amplitude to the 1st (T4:T1).

Executive Summary

This Guideline deals with the recommendations **of Monitoring and Antagonism of Neuromuscular Blockade.**

Neuromuscular Monitoring: Patient Outcomes

1. **When neuromuscular blocking drugs are administered, we recommend against clinical assessment alone to avoid residual neuromuscular blockade, due to the insensitivity of the assessment. (Strong)**
2. **We recommend quantitative monitoring over qualitative assessment to avoid residual neuromuscular blockade. (Strong)**

Neuromuscular Monitoring: Confirmation of Train-of-four Ratio Greater than or Equal to 0.9 before Extubation

3. **When using quantitative monitoring, we recommend confirming a train-of-four ratio greater than or equal to 0.9 before extubation. (Strong)**

Neuromuscular Monitoring: Technical Performance

4. **We recommend using the adductor pollicis muscle for neuromuscular monitoring. (Strong)**
5. **We "recommend against" using eye muscles for neuromuscular monitoring. (Strong)**

Antagonism of Neuromuscular Blockade

6. **We recommend sugammadex over neostigmine at deep, moderate, and shallow depths of neuromuscular blockade induced by rocuronium or vecuronium, to avoid residual neuromuscular blockade. (Strong)**
7. **We suggest neostigmine as a reasonable alternative to sugammadex at minimal depth of neuromuscular blockade. (Conditional)**

Antagonism strategies for Benzylisoquinolinium (Atracurium and Cisatracurium) Neuromuscular Blockade

8. **To avoid residual neuromuscular blockade when atracurium or cisatracurium are administered and qualitative assessment is used, we suggest antagonism with neostigmine at minimal neuromuscular blockade depth. In the absence of quantitative monitoring, at least 10 min should elapse from antagonism to extubation. When quantitative monitoring is utilized, extubation can be done as soon as a train-of-four ratio greater than or equal to 0.9 is confirmed before extubation. (Conditional)**

Introduction

Recent data indicated a high incidence of inappropriate management of neuromuscular block, with a high rate of residual paralysis and relaxant-associated postoperative complications. These data are alarming in that the available neuromuscular monitoring, as well as myorelaxants and their antagonists basically allow well tolerated management of neuromuscular blockade.

In 2023, both the American Society of Anesthesiologists (ASA) and European Society of Anaesthesiology and Intensive Care (ESAIC) published guidelines on the management of neuromuscular blockade [1,2]. Their aim was to present aggregated and evidence-based recommendations to assist clinicians provide best medical care and ensure patient safety. The guidance focuses primarily on the type and site of monitoring and the process of antagonizing neuromuscular blockade to reduce residual blockade. Both societies strongly recommend the use of objective monitors whenever neuromuscular blocking agents (NMBAs) are administered. The 2026 UpToDate topic on monitoring neuromuscular blockade, authored by Renew and Joshi [3], highlights the critical shift toward objective, quantitative monitoring to prevent postoperative residual neuromuscular blockade (RNMB).

This Egyptian Guideline was made in accordance with the 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade.

Purpose and Scope of the guidelines

The purpose of this practice guideline is to provide evidence-based recommendations regarding the appropriate management of neuromuscular monitoring and antagonism of NMBAs during and after general anesthesia. The objective is to provide up-to-date information to guide practice that will enhance patient safety by reducing residual Neuromuscular Blockade.

The guidance focuses primarily on the process of antagonizing neuromuscular blockade to reduce residual neuromuscular blockade (train-of-four ratio less than 0.9), addressing the appropriate type and site of monitoring and the use and dosing of different antagonist drugs depending on the depth of the neuromuscular blockade. Suggestions for implementation of quantitative monitoring are included. The appropriate use of neuromuscular blocking drugs in the context of difficult airway management is not addressed. Additionally, management of intraoperative neuromuscular blockade to optimize intubating conditions, surgical operating conditions, and patient outcomes is not addressed.

The intended patient population: the recommendations in this guideline are intended to be applied to patients undergoing surgical procedures involving use of neuromuscular blockade.
The following guidelines are aimed at providing basic guidelines for incorporating principles of monitoring and antagonism of neuromuscular blockade, with the aim of improving safety outcomes. They are intended as a framework for reasonable and acceptable patient care and should be interpreted as such to allow for some degree of flexibility in different circumstances and according to local practice.

Target Audience

These guidelines are intended for use by healthcare professionals working as Anesthesiologists in all operating suites and intensive care. They also may serve as a resource for healthcare professionals such as operating room and intensive care nurses, perioperative care teams, policy makers, hospital managers, and other stakeholders who advise or care for patients undergoing surgical procedures involving use of neuromuscular blockade.
All physicians applying for privileges in anesthesiology should show satisfactory completion of specialist postgraduate training in anesthesiology, surgical intensive care and pain management, standard training in the Egyptian Board program, University programs or equivalent.

METHODOLOGY

A comprehensive search for the guideline was done to identify the most relevant ones to consider for adaptation. For the literature review, potentially relevant clinical studies were identified *via* electronic and manual searches of the literature. The updated searches covered around 5-year period from January 1, 2020, to May 31, 2026. The inclusion/exclusion criteria that were followed in the search and retrieval of guidelines are adapted.

We selected guidelines only if they are:

- Evidence-based guidelines.
- National and/or international guidelines.
- Guidelines published within the last 5 years.
- Peer reviewed publications.
- Guidelines written in English language.

We Excluded guidelines that are:

- Written by a single author not on behalf of an organization as guideline to be valid and comprehensive, ideally requires multidisciplinary input.
- Published without references as the GDG panel needs to know whether a thorough literature review was conducted and whether the current evidence was used in the preparation of the recommendations.

All retrieved Guidelines were screened and appraised using AGREE II instrument (www.agreetrust.org) by at least three members of the GDG. The panel decided on a cut-off point or ranked the guidelines (any guideline scoring above 50% on the rigor dimension was retained).

Guidelines used in the Adaptation Process:

The basic elements of the Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade published by ASA can be successfully implemented in the practice of anesthesiology. The Guidelines Development Group (GDG) for the Egyptian Board of Anesthetics, Surgical Intensive Care, and Pain Management has adopted with modification:

1. Thilen S R, Weigel W A, Todd MM, et al. 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. January 2023 - Volume 138 - Issue 1 **(Reference No. 1)**

2. Fuchs-Buder T, Romero CS, Lewald H, et al. Peri-operative management of neuromuscular blockade: A guideline from the European Society of Anaesthesiology and Intensive Care. Eur J Anaesthesiol. 2023;40(2):82. Epub 2022 Nov 15. **(Reference No. 2)**

3. Renew JR. Monitoring neuromuscular blockade. UpToDate. Literature review current through: May 2026. Topic last amended: Mar 18, 2026. Support Tag: [0605 – 197.134.92.69 – A2E9CA1045 – PR14 – UPT – NP – 20260610-17:1921UTC] – LG **(Reference No. 3)**

4. Alenezi FK, Alnababtah K, Alqahtani MM, Olayan L, Alharbi M: The association between residual neuromuscular blockade (RNMB) and critical respiratory events: A prospective cohort study. Perioper Med (Lond) 2021; 10:14 **(Reference No. 6)**

5. Weigel WA, Williams BL, Hanson NA, Blackmore CC, Johnson RL, Nissen GM, James AB, Strodtbeck WM: Quantitative neuromuscular monitoring in clinical practice: A professional practice change initiative. ANESTHESIOLOGY 2022; 136:901–15 **(Reference No. 10)**

Strength of Recommendations

The strength of a recommendation communicates the importance of adherence to the recommendation.

Strong Recommendations	The GDG found that the desirable effects of adherence to the recommendation outweigh the undesirable effects. This means that in most situations the recommendation can be adopted.
Conditional Recommendations	This means that the GDG found that there is: ▪ Greater uncertainty about the strength of evidence, or ▪ The recommendation may account for a greater variety in patient values and preferences, or ▪ The resource use makes the intervention suitable for some, but not for other locations. Conditional recommendations are still the best available evidence to date, and it can be adopted if it meets the conditions mentioned with it.
Good Practice Statement (GPS)	Statements based on expert opinion of respected authorities, and the guidelines development groups.

Evidence level

Evidence Assessment

According to WHO Handbook for Guidelines, we used the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) approach to assess the quality of a body of evidence, develop and report recommendations. GRADE methods are used by WHO because these represent internationally agreed standards for making transparent recommendations.

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Detailed GRADE information is available on the following sites:

- GRADE working group: https://www.gradeworkinggroup.org/
- GRADE online training modules: http://cebgrade.mcmaster.ca/

Quality Definition Implications

Evidence is categorized as High, Moderate, Low and Very low.

Table 1: Quality and Significance of the Four Levels of Evidence in GRADE:

Quality	Definition	Implications
High	The guideline development group is very confident that the true effect lies close to that of the estimate of the effect.	Further research is very unlikely to change confidence in the estimate of effect.
Moderate	The guideline development group is moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.	Further research is likely to have an important impact on confidence in the estimate of effect and may change the estimate.
Low	Confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the true effect.	Further research is very likely to have an important impact on confidence in the estimate of effect and is unlikely to change the estimate.
Very low	The group has very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of the effect.	Any estimate of effect is very uncertain.

RECOMMENDATIONS

This Guideline deals with the basic elements of the Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade.

The Guidelines Development Group (GDG) of the Egyptian Board of Anesthetics, Surgical Intensive Care, and Pain Management has adopted with modification:
2023 Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. Thilen S R, Weigel W A, Todd MM, et al. January Anesthesiology 138(1):p 13-41, January 2023. | DOI: 10.1097/ALN.0000000000004379 **(Reference No. 1)** Supported by the American Society of Anesthesiologists and developed under the direction of the Committee on Practice Parameters, Karen B. Domino, M.D., M.P.H. (Chair).

Neuromuscular Monitoring: Patient Outcomes

1. **When neuromuscular blocking drugs are administered, we recommend against clinical assessment alone to avoid residual neuromuscular blockade, due to the insensitivity of the assessment. (Strong, Moderate evidence)**
2. **We recommend quantitative monitoring over qualitative assessment to avoid residual neuromuscular blockade. (Strong, Moderate evidence)**

	Neuromuscular Monitoring: Patient Outcomes
Strength	**Strong**
Benefit of Direction	Beneficial. Quantitative monitoring guarantees full reversal of paralysis.
Evidence	**Moderate strength of evidence.** ASA Task Force 2023 RCTs, observational, prospective and retrospective cohort studies*. Large multinational prospective cohort study, single-institution study, 2 RCTs, single trial and prospective cohort study **
Remarks	The clinical definition of adequate recovery of neuromuscular function may vary when the results of monitoring with acceleromyography are not normalized, and the train-of-four ratio may recover to values greater than 1.0. Normalization of train-of-four ratios to the baseline (control) value obtained before neuromuscular block is accomplished by dividing the postoperative measurements by the baseline value.

***The ASA Task Force panel 2023** [1] identified randomized controlled trials (**RCTs)** [4,5] and **observational studies** [6,7] that reported lower incidences of residual neuromuscular blockade with quantitative monitoring compared with qualitative assessment or clinical assessment. **A prospective study** [6] and a **retrospective cohort study** [7] included comparisons of quantitative monitoring with clinical assessment alone; a before–after design [8] compared quantitative monitoring with peripheral nerve stimulator or clinical assessment—all defined *residual neuromuscular blockade* as a train-of-four ratio less than 0.9 assessed in the PACU.

A **large multinational prospective cohort study [9] did not detect a difference in a composite pulmonary complication outcome (respiratory failure, hypoxia, pulmonary infection or infiltrates, atelectasis, aspiration pneumonia, bronchospasm, or pulmonary edema) in patients with quantitative *versus* qualitative assessment (very low strength of evidence for pulmonary complications). **A single-institution** before–after quality improvement study reported fewer pulmonary complications using quantitative monitoring compared with qualitative assessment [10]. **Two RCTs [5,11]** reported the incidence of hypoxia

(two of the three reported a lower incidence with quantitative monitoring, one no events; low strength of evidence). **A single trial** [5] reported episodes of bronchospasm (1 event, 72 participants), and a **prospective cohort study** [12] reported pneumonia (2 events, 155 participants; both very low strength of evidence). Events were uncommon, and a quantitative evidence synthesis was not performed. It should be noted that there is not one universally accepted definition of postoperative pulmonary complications.

Neuromuscular Monitoring: Confirmation of Train-of-four Ratio Greater than or Equal to 0.9 before Extubation

3. When using quantitative monitoring, we recommend confirming a train-of-four ratio greater than or equal to 0.9 before extubation. (Strong, Moderate evidence)

	Neuromuscular Monitoring: Confirmation of Train-of-four Ratio Greater than or Equal to 0.9 before Extubation
Strength	**Strong**
Benefit of Direction	Beneficial. Confirming a train-of-four ratio greater than or equal to 0.9 decrease the risk of residual neuromuscular blockade.
Evidence	**Moderate strength of evidence.** The ASA Task Force 2023 with 41 studies included in the body of evidence, European Society of Anaesthesiology and Intensive Care (ESAIC)*. RTCs comparing TOF ratios before extubation are lacking**.
Remarks	The results are consistent with less residual neuromuscular blockade when a train-of-four ratio greater than or equal to 0.9 is confirmed before extubation, but limitations in these analyses are important to note.

***The ASA Task Force 2023** [1] **summary of evidence** stated that patients whose train-of-four ratio was confirmed before extubation experienced less residual neuromuscular blockade compared to when the train-of-four ratio was not confirmed after neostigmine or sugammadex**.** The body of evidence included **41 studies** (26 RTCs, 1 before–after design, 4 nonrandomized trials, 6 prospective cohort studies, 3 retrospective cohort studies, and 1 fully paired study) using quantitative monitoring and sugammadex or neostigmine and reporting residual NMB (train-of-four ratio less than 0.9) [1]. This summary of evidence coincides with those of the **European Society of Anaesthesiology and Intensive Care (ESAIC)** guideline on peri-operative management of neuromuscular block [2]. **Direct evidence from randomized trials that compare confirming or not confirming train-of-four ratios before extubation **are lacking**.

When sugammadex was used and a train-of-four ratio greater than or equal to 0.9 was confirmed before extubation, the pooled incidence proportion of residual neuromuscular blockade (train-of-four ratio less than 0.9) was 0.5% (95% CI, 0.0 to 6.0%). If a train-of-four ratio greater than or equal to 0.9 was not confirmed before extubation, although quantitative monitoring was used, the incidence proportion was 2.2% (95% CI, 0.5 to 9.0%). With neostigmine, the pooled incidence proportions were 5.3% (95% CI, 2.5 to 10.7%) and 44.9% (95% CI, 29.9 to 60.8%), respectively, with and without confirmation. (https://links.lww.com/ALN/C929) displays the entirety of the results (**moderate strength of evidence** for train-of-four ratio greater than or equal to 0.9 confirmation before extubation) [1].

Neuromuscular Monitoring: Technical Performance

4. **We recommend using the adductor pollicis muscle for neuromuscular monitoring. (Strong, Moderate evidence)**
5. **We "recommend against" using eye muscles for neuromuscular monitoring. (Strong, Moderate evidence)**

	Neuromuscular Monitoring: Technical Performance
Strength	**Strong**
Benefit of Direction	Beneficial. Complete recovery of all muscles from neuromuscular blockade (NMB) optimizes patient safety; therefore, measurements should be obtained at sites with longer times to recovery.
Evidence	**Moderate strength of evidence.** ASA Task Force 2023, ESAIC guideline *. Comparative, randomized and prospective observational studies**.
Remarks	Complete recovery of all muscles from neuromuscular blockade optimizes patient safety; therefore, measurements should be obtained at sites with longer times to recovery. When monitoring a muscle with relative resistance such as the eye muscles to neuromuscular blocking drugs, there is a potential for neuromuscular blocking drug overdose and for concluding that a patient is adequately antagonized when, in fact, they are not.

***The ASA Task Force 2023** [1] **summary of evidence** stated that time to reach train-of-four ratio greater than or equal to 0.9 at the adductor pollicis muscle was longer compared with eye muscles and flexor hallucis brevis. There was less residual neuromuscular blockade when patients were monitored at the adductor pollicis muscle compared to the corrugator supercilii. These recommendations are in line with those of the **European Society of Anaesthesiology and Intensive Care (ESAIC)** guideline [2].

****Comparative, randomized and prospective observational studies** showed that Times to train-of-four ratio greater than or equal to 0.8, 0.9, or 1.0 were longer in patients monitored with the adductor pollicis muscles compared with the corrugator supercilii (moderate strength of evidence), orbicularis oculi (low strength of evidence), and flexor hallucis brevis muscles (very low strength of evidence) [13-16]. No difference was detected in the time to train-of-four ratio greater than or equal to 0.9 when monitoring the adductor pollicis muscle compared with the masseter (very low strength of evidence) [17].

Antagonism of Neuromuscular Blockade

6. **We recommend sugammadex over neostigmine at deep, moderate, and shallow depths of neuromuscular blockade induced by rocuronium or vecuronium, to avoid residual neuromuscular blockade. (Strong, Moderate evidence)**
7. **We suggest neostigmine as a reasonable alternative to sugammadex at minimal depth of neuromuscular blockade. (Conditional, Low evidence)**

	Antagonism of Neuromuscular Blockade
Strength	**Strong** for sugammadex over neostigmine **Conditional** for neostigmine as an alternative to sugammadex at minimal depth of NMB
Benefit of Direction	Beneficial. Lower incidence of residual NMB in patients antagonized with sugammadex compared with neostigmine.
Evidence	**Moderate strength of evidence** for sugammadex over neostigmine. The ASA Task Force 2023, Several RCTs*

	Low strength of evidence for neostigmine as an alternative to sugammadex at minimal depth of NMB: Several studies and Comparative studies**.
Remarks	The FDA-approved dose recommendations for antagonizing rocuronium or vecuronium with sugammadex are 2 mg/kg for train-of-four count 2 to train-of-four ratio less than 0.9, 4 mg/kg for post-tetanic count 1 to train-of-four count 1, and 16 mg/kg immediate antagonism after administration of a single dose of rocuronium 1.2 mg/kg. A neostigmine dose of 30 µg/kg at minimal neuromuscular blockade is consistent with the FDA-approved dosage recommendations.

***The ASA Task Force 2023** [1] **summary of evidence** showed that the incidence of residual neuromuscular blockade was lower and time to recovery to Train-of-four Ratio Greater than or Equal to 0.9 was shorter with sugammadex compared to neostigmine. However, there were no differences in re-paralysis and reintubation rates. **Several randomized controlled trials** [18-20] reported a lower incidence of residual neuromuscular blockade in patients antagonized with sugammadex compared with neostigmine (moderate strength of evidence; https://links.lww.com/ALN/C929). Times to train-of-four ratio greater than or equal to 0.9 were shorter in patients antagonized with sugammadex compared with neostigmine from deep [21] to moderate [22,23] depths of blockade (moderate strength of evidence) and from shallow [24] (moderate strength of evidence) to minimal [21] depths of blockade (very low strength of evidence; https://links.lww.com/ALN/C929).

****Several studies** have demonstrated that administering neostigmine at a train-of-four count of 4 is much more likely to yield a satisfactory and timely antagonism than neostigmine administered at a lower train-of-four count [25,26]. However, it is also clear from several studies that an effective antagonism is not guaranteed even when spontaneous recovery has progressed to a train-of-four count of 4 if the fourth twitch is still very weak [25]. In **one study**, a cohort of patients were antagonized when the train-of-four ratio was 0.4, and all patients had a timely successful antagonism as defined by a train-of-four ratio greater than or equal to 0.9 within 10 min of neostigmine administration [27]. **Another study compared** sugammadex with neostigmine at a train-of-four ratio of 0.5 and found that both were equally effective at this depth of blockade [28]. **Additional studies** have confirmed that the likelihood of an effective antagonism with neostigmine is much improved when the neuromuscular blockade is minimal (*minimal block* is the proposed consensus term for a quantitatively measured block with a train-of-four ratio of 0.4 to 0.9, or a qualitatively assessed block with no subjective fade to train-of-four stimulation) [28-30]. The quantitative determination of train-of-four ratio greater than or equal to 0.4 is more reliable than subjective determination of no fade with train-of-four stimulation and is associated with improved predictability of neostigmine.

Antagonism Strategies for Benzylisoquinolinium (Atracurium and Cisatracurium) Neuromuscular Blockade

8. To avoid residual neuromuscular blockade when atracurium or cisatracurium are administered and qualitative assessment is used, we suggest antagonism with neostigmine at minimal neuromuscular blockade depth. In the absence of quantitative monitoring, at least 10 min should elapse from antagonism to extubation. When quantitative monitoring is utilized, extubation can be done as soon as a train-of-four ratio greater than or equal to 0.9 is confirmed before extubation. (Conditional, Very low evidence)

	Antagonism strategies for benzylisoquinolinium (*atracurium and* cisatracurium) neuromuscular blockade
Strength	**Conditional**

Benefit of Direction	Beneficial. Safe full antagonism strategies for benzylisoquinolinium (atracurium and cisatracurium) NMB
Evidence	**Very low strength of evidence:** The ASA Task Force 2023, Six studies*.
Remarks	Benzylisoquinolinium neuromuscular blocking drugs (cisatracurium and atracurium) can be antagonized only with an acetylcholinesterase inhibitor such as neostigmine—sugammadex is ineffective.

***The ASA Task Force 2023** [1] **summary of evidence** showed that times to train-of-four ratio greater than or equal to 0.9 after neostigmine administration ranged from 1 to 143 min reported in **six studies** [31, 25, 27, 32-34] (https://links.lww.com/ALN/C929; very low strength of evidence). Time to train-of-four ratio greater than or equal to 0.9 for neostigmine antagonism of cisatracurium and atracurium showed a mean, min (SD) time of 10.3 (1.3) min [32] and wide range for Median, min (Range) from 4 (3-6) [27] to 16.5 (6.5-143.3) [25]

Benzylisoquinolinium NMB drugs (cisatracurium and atracurium) can be antagonized only with an acetylcholinesterase inhibitor such as neostigmine—sugammadex is ineffective. However, neostigmine can be accompanied by a longer time to recovery than may be recognized. Assuming that (i) neostigmine is given once a muscle relaxant is no longer required for surgery, (ii) there is some spontaneous recovery from neuromuscular blockade, and (iii) emergence from anesthesia is expected in approximately 10 min, antagonism success depends primarily on the depth of block at the time of administration. Full antagonism within 10 min is most likely when neostigmine is given with four twitches and no visible or tactile fade. Success is unlikely when given with fewer than four twitches. Under these circumstances limited evidence is consistent with a median time to antagonism less than 10 min, but with a wide range in time to recovery from a train-of-four ratio of less than 0.4 to a train-of-four count 2 to 3 blockade [25, 27, 31-34]. Therefore, verifying adequate recovery necessitates measuring train-of-four ratio with a quantitative monitor.

Implementation Considerations

- Acceptance and implementation of routine quantitative monitoring for patients receiving NMB agents represents a change in clinical practice.
- Strategies for implementation of routine quantitative monitors are infrequently available, and peripheral nerve stimulators used in anesthetics when patients receive NMBs is limited.
- Many clinicians continue to use clinical indicators such as sustained head lift to guide their decision on when to extubate patients. There is no clinical test that is predictive of adequate NM recovery and clinical tests are not applicable when the patient is still under anesthesia.
- Increasing opportunities to accelerate adoption of quantitative monitoring and improve patient outcomes in the operating room. The clinician needs reliable information as to the patient's NM function before emergence from anesthesia.
- There have been multiple calls to follow guidelines to monitor depth of NMB because of the benefits of complete recovery including increased patient satisfaction, decreased length of PACU stay, decreased postoperative pulmonary complications, and decreased mortality.
- Placing monitors in all anesthetizing locations and involving the department end users in the equipment purchasing decision of the more recent broader range of commercially available equipment choices.
- Educational efforts for the trainee anesthesia clinicians of the importance and benefits of routine quantitative monitoring; utilizing different mediums equipment, instructional videos,

alerts built into the electronic medical record for real-time reminders to record train-of-four ratios and performance feedback.

Research Gaps

Literature review shows insufficient research data that need further studies for:

- Studies to confirm that an electromyography train-of-four ratio greater than or equal to 0.9 is associated with improved patient outcomes.
- The dose of sugammadex required for rocuronium when compared with vecuronium at the same depths of blockade, as sugammadex has a greater affinity for rocuronium than vecuronium.
- The effects of residual neuromuscular blockade need to be further studied, focusing upon postoperative pulmonary complications and higher-risk surgical patients.
- Direct evidence from randomized trials that compare confirming or not confirming train-of-four ratios before extubation are lacking.

Clinical Indicators for Monitoring

- **Percentage of patients monitored with quantitative neuromuscular blockade**
  Numerator: Number of patients monitored with quantitative NMB
  Denominator: Total number of patients who received NMB agents
- **Percentage of patients with a documented train-of-four ratio greater than or equal to 0.9**
  Numerator: Number of patients with a documented train-of-four ratio greater than or equal to 0.9
  Denominator: Total number of patients who received NMB agents
- **Incidence of patients with residual paralysis in the PACU**
  Numerator: Number of patients with residual paralysis in the PACU
  Denominator: Total number of patients who received NMB agent
- **Incidence of reintubation associated with residual paralysis**
  Numerator: Number of reintubated patients at the PACU associated with residual paralysis
  Denominator: Total number of patients who received NMB agent
- **Incidence of** postoperative pulmonary complications
  Numerator: Number of patients who have pulmonary complications within 7 days post recovery
  Denominator: Total number of patients who received NMB agent

Update of the Guideline

The Guidelines of this current version (Year 2026) are subject to revision, and the updated versions will be published when needed, as warranted by the evolution of new-evidenced medical knowledge, new technology, and new practice trends.

Guidelines Development Contributors and Participants

Contributors and Participants:
The Guidelines Development Group (GDG) of the Egyptian Board of Anesthesia, Surgical Intensive Care, and Pain Management.

Annexes

Annex 1:

Evidence-to-Decision Tables

1. Monitoring Neuromuscular Blockade

Domain	Evidence Summary
Problem	Residual neuromuscular blockade increases the risk of hypoxemia, airway obstruction, aspiration, and postoperative complications.
Benefit	Objective monitoring (quantitative train-of-four [TOF]) reduces the incidence of residual paralysis and improves patient safety.
Benefit Direction	Strongly positive – consistent reduction in adverse outcomes.
Risk/Harm	Minimal; requires equipment and training. False reassurance is possible if only qualitative monitoring is used.
Certainty of Evidence	Moderate to high – multiple RCTs and meta-analyses support quantitative monitoring.
Values and Preferences	Patients & clinicians value safety, avoidance of reintubation & smooth recovery.
Resource Use	Requires investment in quantitative monitors; costs vary but are generally modest compared to the potential complications.
Equity	Access may be limited in resource-constrained settings; high-income centers are more likely to adopt.
Acceptability	High among anesthesiologists; increasingly considered standard of care.
Feasibility	Feasible with training and institutional support; barriers include equipment availability.
Recommendation	**Strong recommendation**: Use quantitative neuromuscular monitoring whenever neuromuscular blocking agents are administered.

2. Choice of Reversal Agent (Neostigmine vs. Sugammadex)

Domain	Neostigmine	Sugammadex
Problem Addressed	Routine reversal of shallow/moderate blockade	Rapid reversal of aminosteroid blockade, even deep
Benefit	Effective, inexpensive	Highly effective, rapid, predictable
Benefit Direction	Positive but limited	Strongly positive
Risk/Harm	Bradycardia, incomplete reversal	Rare hypersensitivity, high cost
Certainty of Evidence	High	High
Values & Preferences	Acceptable, widely used	Preferred when speed/safety critical
Resource Use	Low cost	High cost
Equity	Widely available	Limited in resource-constrained settings
Acceptability	High	High, but a cost barrier
Feasibility	Easy, requires an anticholinergic	Easy, no adjunct needed
Recommendation	Use for routine cases	Use when rapid, reliable reversal needed

3. Antagonism of Neuromuscular Blockade

Domain	Evidence Summary
Problem	Residual blockade persists if antagonism is not performed or is inadequate, leading to respiratory complications.
Benefit	Antagonists (neostigmine, sugammadex) reliably reverse blockade, reducing postoperative complications.
Benefit Direction	Strongly positive – reversal agents improve safety and recovery.
Risk/Harm	Neostigmine: risk of bradycardia, incomplete reversal if given too early. Sugammadex: rare hypersensitivity, higher cost.
Certainty of Evidence	High – robust evidence supports the efficacy of both agents.
Values and Preferences	Patients value rapid, safe recovery; clinicians prefer predictable reversal. Sugammadex often preferred for aminosteroid agents due to speed and reliability.
Resource Use	Neostigmine is inexpensive; sugammadex is costly but may reduce ICU admissions and complications.
Equity	Sugammadex availability is limited in low-resource settings; neostigmine is widely accessible.
Acceptability	High; sugammadex is increasingly accepted despite cost.
Feasibility	Both agents are feasible; the choice depends on institutional resources and drug availability.
Recommendation	**Strong recommendation**: Always antagonize neuromuscular blockade unless full recovery is objectively confirmed. Prefer sugammadex for aminosteroid agents when available; otherwise, use neostigmine with appropriate monitoring.

4. Perioperative Safety & Systems

Domain	Evidence Summary
Problem	Residual blockade contributes to morbidity, ICU admissions, and prolonged recovery.
Benefit	Standardized monitoring and reversal protocols reduce complications.
Benefit Direction	Strongly positive.
Risk/Harm	Minimal; requires institutional buy-in.
Certainty of Evidence	Moderate–high.
Values & Preferences	Strong preference for patient safety.
Resource Use	Institutional investment in monitors and drug supply.
Equity	Disparities in access to sugammadex and monitors.
Acceptability	High among clinicians and patients.
Feasibility	Feasible with training, guidelines, and policy support.
Recommendation	**Strong recommendation**: Implement institutional protocols for monitoring and reversal to ensure patient safety.

Annex 2:

Key Stimulation Modalities

- **Train-of-Four (TOF):** The gold-standard test delivering 4 rapid impulses at 2 Hz. It tracks "fade," measuring the ratio of the 4th twitch amplitude to the 1st (T4:T1).
- **Post-Tetanic Count (PTC):** Used for intense blocks when TOF shows 0 twitches. A 50 Hz stimulus is given followed by single twitches to gauge how close the patient is to returning to a measurable TOF.
- **Double Burst Stimulation (DBS):** Two short bursts of tetanic stimuli used to make visual/tactile fade easier to spot when electronic tools are limited.

Depth Classifications

The depth of paralysis is clinically staged by muscle responses:

- **Deep Block:** PTC ≥ 1, but TOF count is 0.
- **Moderate Block:** TOF count reads 1 to 3 twitches.
- **Shallow Block:** TOF count is 4, but the TOF ratio is < 0.4.
- **Minimal Block:** TOF ratio is between 0.4 and < 0.9.
- **Acceptable Recovery:** TOF ratio is ≥ 0.9.

Annex 3:

Monitoring Sites [1]

While different eye muscles have different characteristics, distinguishing the evoked responses from orbicularis oculi and corrugator supercilii muscles is often difficult **[14]**. We therefore make the same recommendations for all eye muscles. The adductor pollicis muscle recovers more slowly than the corrugator supercilii or orbicularis oculi muscle. There are higher simultaneous train-of-four ratios at the corrugator supercilii, and orbicularis oculi muscles compared with the adductor pollicis. *Residual neuromuscular blockade* is defined as a train-of-four ratio less than 0.9 at the adductor pollicis muscle, and it is therefore optimal to confirm adequate recovery by obtaining a valid measurement at this site. A valid measurement of the depth of the neuromuscular blockade is also essential to guide selection of the pharmacological antagonist drug and dosage. Therefore, if intraoperative neuromuscular monitoring has been performed at the eye muscles because no other site was easily accessible intraoperatively, then we recommend changing the site to the adductor pollicis muscle before antagonism. Dosage recommendations for pharmacological antagonist drugs are based on the adductor pollicis muscle responses. When monitoring at the corrugator supercilii muscle, dosage recommendations approved by the FDA for sugammadex are not applicable **[15]**. For these reasons, the adductor pollicis muscle is a safer option than the orbicularis oculi or corrugator supercilii. The time to recovery is similar between the adductor pollicis and masseter muscles, although the data are very limited.

In the hand, there are three muscles most commonly monitored using electromyography. These muscles are the adductor pollicis (palmar portion of the thumb), the first dorsal interosseous (posterior aspect of hand between the thumb and index finger), and the abductor digiti minimi (medial aspect of palm proximal to the pinky finger). The reference site of measurement is the adductor pollicis muscle. Train-of-four ratios at the adductor pollicis and first dorsal interosseous

muscles are similar when measured simultaneously, and therefore, it appears reasonable to use data interchangeably between these sites, especially if the adductor pollicis muscle is not available or signal quality is poor. Train-of-four ratios at the adductor pollicis muscle are lower than the abductor digiti minimi when measured simultaneously, indicating a relative resistance to neuromuscular blockade at the abductor digiti minimi. Therefore, data from the abductor digiti minimi muscle should be used with caution to guide neuromuscular blockade management (understanding the patient is more deeply paralyzed than the monitor indicates). Direct comparisons of the two alternate muscles, the first dorsal interosseous and the abductor digiti minimi, reveal the same pattern of relative resistance at the abductor digiti minimi muscle, reinforcing that measurements at the adductor pollicis and the first dorsal interosseous offer a higher margin of patient safety.

The time to recovery is similar between the adductor pollicis and masseter muscles, although the data are very limited. The data on the flexor hallucis muscle are inconsistent; however, the time to recovery is more similar between the adductor pollicis and flexor hallucis than between adductor pollicis and the eye muscles.

Annex 4:

Strategies for Implementation and Acceptance of Routine Quantitative Monitoring [1]
○ Educate clinicians on the prevalence and consequences of residual neuromuscular blockade in routine care; provide key references. ○ Provide in-service training on quantitative monitoring technology, emphasizing the increasing ease of use and interpretation. ○ Work with the operating room value-based-purchasing committee (or local equivalent) to define appropriate indications and contraindications for quantitative monitoring. Include all patients receiving neuromuscular blocking drugs, with particular focus on patients receiving nondepolarizing neuromuscular blocking drug. ○ Ensure that monitors are readily available. ○ Seek opportunities to document and promote results within your group and institution to enable: - A decrease in incidence of postoperative respiratory complications. - A decrease in ICU and hospital length of stay. - An increase in patient satisfaction. - Changes in the use of antagonist drugs. ○ Provide team and individual feedback on appropriate use of quantitative monitoring.

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