Pediatric Anesthesia and Critical Care Journal 2025;13(1):17-33
doi:10.14587/paccj.2025.4

PACCJ

National survey on the use of neuromuscular blockers and reversal in adult, pediatric and pregnant patients

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Keypoints

1. Neuromuscular-blocking drugs, or Neuromuscular blocking agents (NMBAs), block transmission at the neuromuscular junction, causing paralysis of the affected skeletal muscles. This is accomplished via their action on the post-synaptic acetylcholine (Nm) receptors.
2. This class of medications helps to reduce patient movement, breathing, or ventilator dyssynchrony and allows lower insufflation pressures during laparoscopy. It has several indications for use in the intense care unit. It can help reduce hoarseness in voice as well as injury to the vocal cord during intubation. In addition, it plays an important role in facilitating mechanical ventilation in patients with poor lung function.
3. Neuromuscular block can be reversed once recovery has commenced with anticholinesterases. In contrast, the novel cyclodextrin sugammadex can be used to reverse any degree of neuromuscular block produced by rocuronium or vecuronium.
4. This survey reports the results conducted to obtain information on current anesthetic practices regarding the use of neuromuscular blockers, their reversals, and neuromuscular monitoring, the incidence of PORC in pediatric, adult, and pregnant patients.

Abstract

Introduction

This study presents the findings of an Italian investigation through SIAATIP - Italian Society of Anesthesia, Analgesia and Pediatric Intensive Care - aimed at gathering data on current anesthetic practices related to the use of neuromuscular blockers, their reversal agents, and neuromuscular monitoring in pediatric, adult, and pregnant patients. The study focused on several key areas: the types of neuromuscular blockers used, the frequency of neuromuscular monitoring, the safe TOF Ratio values for assessing recovery from neuromuscular blockade, the use

and side effects of reversal agents, and the incidence of postoperative residual curarization (PORC).

Materials and methods

A digital questionnaire was distributed through links, social media, and word of mouth to specialist physicians and those in specialized training in Anesthesia, Intensive Care, and Pain Therapy across Italy. The questionnaire aimed to gather information about clinical practices related to neuromuscular blockade, categorized by patient type (adult, pediatric, or pregnant). Respondents provided details on the type of neuromuscular blocker used, neuromuscular monitoring methods and extubation parameters, documentation practices, reversal agents and their side effects, and the incidence of postoperative residual curarization (PORC).

Data were collected from February 1, 2023, to March 19, 2024, anonymously. Responses were analyzed based on percentages and stratified by age, geographic location, and workplace type (public or private).

Results

While sugammadex is widely used across all patient groups, neuromuscular monitoring remains inconsistent, and residual neuromuscular blockade (PORC) continues to be a concern despite its use. Monitoring practices and adherence to guidelines like TOF values appear to be better in specialized training centers.

Conclusion

The study emphasizes the critical need for proper monitoring and reversal practices with neuromuscular blockers, as neglecting these can jeopardize patient safety. The findings underline the importance of aligning clinical practices with guidelines, especially in pediatric and pregnant populations, where specific competencies and considerations are necessary.

Keywords

Neuromuscular blockers; reversal agent for neuromuscular blockade; neuromuscular blockade management; residual neuromuscular blockade; neuromuscular monitoring systems; PRNB; PORC; anesthetic practice.

Introduction

Despite more than 70 years since the introduction of neuromuscular blockers in anesthetic practice, anesthetists still face daily challenges regarding the correct management of neuromuscular blockade and the subsequent recovery from it. The advent of sugammadex as a reversal agent for neuromuscular blockade, along with neuromuscular monitoring systems, has significantly advanced this area.

The incidence of postoperative residual neuromuscular blockade (PRNB) or postoperative residual curarization (PORC) remains a concern: an unacceptably high number of patients are estimated to leave the operating room with residual paralysis, leading to various complications. To address the heterogeneity in the management of neuromuscular blockade, scientific societies have formulated specific guidelines over the years. National societies have slowly begun to include the management of neuromuscular blockade in their anesthesia standards or even develop dedicated guidelines. However, the specifics of these standards and guidelines vary widely.

The 2018 Good Clinical Practice guidelines from the Italian Society of Anesthesia, Analgesia, Resuscitation, and Intensive Care (SIAARTI) outline the fundamental principles for the use of neuromuscular blockers, their reversal agents, and monitoring systems. In addition to the persistent heterogeneity in this area both nationally and internationally, there is currently a lack of national data on the types, frequency, and settings (such as surgical procedures or patient types) for the use of neuromuscular blockers, reversal agents, and neuromuscular monitoring. There is also a lack of data documenting different approaches to assessing the risk of PORC, and especially a lack of data that can accurately describe how and whether sugammadex has influenced the choice of neuromuscular agent, monitoring practices, and overall anesthetic practice.

Neuromuscular Blockade: Neuromuscular Blockers

Muscle relaxants are drugs used during surgical procedures to facilitate tracheal intubation, mechanical

ventilation, and surgical maneuvers. Proper management of neuromuscular blockade through monitoring systems is necessary to safely control the recovery phase from neuromuscular blockade at the end of anesthesia, preventing postoperative residual curarization and the associated risks of primarily respiratory complications.

The success of anesthesia management in various patients depends on a precise understanding of the physiological, anatomical, and pharmacological differences between pediatric patients of all ages and adults, as well as pregnant women. Unlike adults, a child's body is in constant and progressive evolution: the growth of body size is accompanied by anatomical changes and, more importantly, the development of all its functions, which mature until gradually reaching adult conditions. Therefore, a child cannot be considered "a small adult" but rather a being undergoing continuous change, passing through numerous phases, each with its own characteristics while still connected to the preceding and subsequent phases. The pharmacokinetics and pharmacodynamics of neuromuscular blockers differ in children compared to adults. These physiological and pharmacological differences arise from various factors: incomplete neuromuscular maturation; a higher percentage of extracellular fluid, affecting the distribution of polar drugs like muscle relaxants; and reduced organ-dependent clearance.

Pregnancy brings about numerous changes in a woman's body, most of which resolve after childbirth. All systems are affected, starting from the respiratory system to the reproductive system, including the cardiovascular system, with modifications that make the pregnant woman a distinct patient, much like the pediatric patient.

All available neuromuscular blockers are quaternary ammonium compounds. They are structurally related to acetylcholine (ACh), which contains a quaternary nitrogen group (N + [CH3] 3). Similar to ACh, the positively charged nitrogen atoms of muscle relaxants are attracted to the α subunits of the postsynaptic nicotinic receptor. Many neuromuscular blockers (e.g., succinylcholine and atracurium) contain two quaternary ammonium cations. These bisquaternary amines are more potent than monoquaternary amines (e.g., rocuronium and vecuronium), which have only one permanent quaternary cation and a tertiary amine. However, at physiological pH, especially in acidic conditions, the tertiary amine can become protonated and thus positively charged, increasing the potency of monoquaternary non-depolarizing neuromuscular blockers (NMBDs). This has clinical significance: the effect of such NMBDs is enhanced in patients with acidosis. The common mechanism of action is that neuromuscular blockers act at different sites of the neuromuscular junction, but their main effects manifest as agonism and antagonism of postsynaptic nicotinic receptors.

Neuromuscular blockers can be classified in various ways; depending on their mechanism of action at the neuromuscular junction, they are categorized as depolarizing and non-depolarizing; based on their chemical composition (only non-depolarizing), they can be further divided into aminosteroids and benzyl-isoquinolines; based on their duration of action, they can be classified as long, intermediate, or short-acting. The only depolarizing neuromuscular blocker currently available on the market is succinylcholine (composed of two ACh molecules linked by a methyl acetate group, with the two quaternary ammonium radicals binding to the two α subunits of the nicotinic receptor, causing depolarization); it has a rapid onset (60s) at a dose of 1-1.5 mg/kg in adults and is still used for rapid sequence intubation (RSI). It is not routinely recommended in children due to serious complications (cardiac arrest with hyperkalemia, acidosis, rhabdomyolysis) observed in apparently healthy individuals. Due to the multiple unwanted side effects it may present, the preference today is for non-depolarizing neuromuscular blockers.

Among non-depolarizing neuromuscular blockers, rocuronium is currently the most frequently used drug in clinical practice. Rocuronium is structurally derived from vecuronium, has an intermediate duration of action, and has a potency of 1/6 that of vecuronium. Thanks to its

lower potency, it has the shortest onset among all available NMBDs. Due to its rapid onset at full dosage (1.2 mg/kg), it can be defined as the non-depolarizing analogue of succinylcholine but with a longer duration. It does not appear to release histamine or interfere with its metabolism. It has highly variable and unpredictable elimination kinetics and is also indicated for pediatric patients, from term neonates to adolescents. It belongs to the class of aminosteroid neuromuscular blockers, is metabolized almost exclusively in the liver (due to its lipophilicity), and is excreted renally.

Benzyl-isoquinolines, the other major class of non-depolarizing neuromuscular blockers, undergo degradation that is almost entirely plasma-dependent, hence not organ-dependent (Hoffman reaction), but they tend to release histamine. Cisatracurium is the only compound from this class still used in anesthesia: it is the cis isomer of atracurium, four times more potent than it, with longer onset and duration, and is characterized by the absence of histamine release. Due to its plasma degradation, it can be administered continuously without the risk of accumulation. It does not show significant differences in onset between children and adults. Stable in acidic environments, it should not be administered with propofol or alkaline solutions in the same infusion line.

Recent national and international guidelines have attempted to standardize the safe use of these drugs. They recommend the use of muscle relaxants to reduce pharyngeal and/or laryngeal injuries during endotracheal intubation. They also state that it is not advisable to check for mask ventilation before administering the muscle relaxant. In contrast, in the absence of difficult mask ventilation criteria, there is strong evidence that the muscle relaxant facilitates easier mask ventilation. There is no evidence that any muscle relaxant is superior to others under standard conditions. The choice of drug may be based on patient characteristics and the expected duration of general anesthesia. For rapid sequence induction (RSI), both succinylcholine and rocuronium at a dose of 1-1.2 mg/kg are indicated, as their rapid action at that dose is comparable.

Muscle relaxants are among the drugs used in anesthesia that globally expose patients the most to the risk of allergic reactions. In the case of a suspected allergic reaction during anesthesia, it would be advisable to immediately perform a blood sample for serum histamine and tryptase levels, followed by referral to a specialized allergy center.

Monitoring Systems

All current guidelines agree on the necessity of employing neuromuscular monitoring to ensure a full recovery of muscle function after general anesthesia. A clinical evaluation based on the patient's ability to lift their head, stick out their tongue, squeeze a hand, or breathe spontaneously, cough, or move extremities on command is inadequate to rule out residual neuromuscular block, with a sensitivity of 10–30% and positive predictive values of less than 50% at best. It is important to remember that while recovery of diaphragmatic contractility ensures adequate ventilation early on, the muscles of the upper airways are characterized by delayed recovery, predisposing to obstruction and inadequate airway protection. Even qualitative (subjective) monitoring of peripheral nerves cannot guarantee adequate recovery from neuromuscular block, thus failing to exclude a residual neuromuscular block (RNB).

Quantitative (objective) neuromuscular monitoring is essential, as it is the only method that can ensure adequate recovery from neuromuscular block and should be used whenever neuromuscular blocking agents (NMBDs) are administered, regardless of the type (there have been reported cases of residual paralysis and re-intubation due to cholinesterase deficiency in patients administered succinylcholine and mivacurium). Monitoring should begin prior to the administration of NMBDs and continue throughout the duration of the procedure until awakening. Although peripheral nerve stimulators were introduced in the 1950s, the era of quantitative assessment of

neuromuscular block began with the introduction of the train of four (TOF), which most commonly involves stimulating the ulnar nerve and subsequently assessing contractions of the adductor pollicis muscle. Alternatively, other nerves such as the facial nerve (assessing the contraction of the orbicularis oculi) and the tibial nerve (assessing the contraction of the hallux) can be stimulated. As the depth of neuromuscular block increases, the sequential contractions decrease in amplitude (from the fourth to the first): the numerical calculation of the ratio between the amplitude of the fourth and first contractions provides the TOF Ratio (TOF-R), an essential guide for monitoring the degree of neuromuscular block, safely proceeding with extubation, and preventing postoperative residual curarization phenomena. These quantitative measurements have objectively determined the presence of residual neuromuscular block after surgery.

Currently, recovery of neuromuscular function is defined as a TOF-R greater than or equal to 0.9. Literature data confirm that residual neuromuscular block remains a not infrequent occurrence at the end of surgical procedures and/or in the post-anesthesia care unit (PACU). Many factors contribute to maintaining this high incidence: primarily the significant variability in the duration of action of neuromuscular blockers, the use of "clinical" assessments of muscle paralysis, and subjective evaluations of responses to peripheral nerve stimulation.

Guidelines agree that neuromuscular monitoring should be adopted during surgery, at least when it is necessary to administer multiple doses of muscle relaxants or employ continuous administration of the same. Monitoring is mandatory in cases requiring deep block (TOF=0, PTC=1-2) or in cases of severe hepatic or renal insufficiency or neuromuscular diseases.

Among neuromuscular monitoring systems based on acceleromyography, post-tetanic count (PTC) should be mentioned, which is used to evaluate the intensity of neuromuscular block when the TOF response is equal to 0. It consists of a defined "tetanus" stimulation, i.e., 50 Hz for 5 seconds, followed after 3 seconds by 15 single stimuli at 1 Hz. The number of evoked responses will be inversely correlated to the depth of the block. This system is useful for establishing the timing of the onset of neuromuscular recovery and especially for differentiating a deep block from a moderate block (timing for possible reversal). It is referred to as intense or complete block when TOF 0 and PTC 0, deep block when there is at least one response to PTC and TOF 0, and moderate block if TOF 1-3.

Current national guidelines also remind us of the importance of always documenting the values obtained from neuromuscular transmission monitoring during surgical phases and, especially, at extubation and discharge from the operating room/Recovery room.

Reversal of Neuromuscular Block

Complete recovery from neuromuscular block is necessary to avoid RNB and the potential morbidity related to it, predominantly pulmonary. Spontaneous recovery is certainly possible, but its adequacy cannot be verified by qualitative monitoring; moreover, in the presence of 4 responses to TOF stimulation, it still requires the administration of a reversal agent. A TOF-R value > 0.92 is indicative of valid recovery from neuromuscular block (with an optimal ratio equal to 1).

Both RNB and its complications are likely underestimated: appropriate quantitative monitoring, essential in the recovery phase from deep block, can effectively eliminate its incidence. A correlation has been demonstrated between the non-use of reversal agents and unfavorable outcomes, from pneumonia to re-intubation to death.

Regarding postoperative pulmonary complications, it is worth mentioning the multicenter observational study POPULAR, which enrolled over 20,000 patients from 211 hospital centers across 28 European countries: the study examined the potential correlation between the incidence of postoperative pulmonary complications and the "inappropriate" use of muscle relaxants and/or reversal agents and/or monitoring of neuromuscular transmission in general surgical anesthesia. The results confirm a correlation between the use of neuromuscular blockers

and an increase in postoperative complications (particularly significant in patients with few or no specific risk factors); the study also indicates that neither quantitative monitoring (with extubation at TOF-R ≥ 0.9) nor pharmacological recovery (even with sugammadex) reduce the risk of complications: the authors conclude that "patients with a low risk of postoperative pulmonary complications should be anesthetized without the use of muscle paralysis whenever possible." In other words, the anesthetist is called to evaluate the risk-benefit ratio of muscle relaxants, especially in patients in good overall condition undergoing minor surgical procedures, for whom alternative anesthetic methods that do not require muscle block should be preferred. The European study is inevitably destined to spark intense discussions, as it is a common opinion, based on numerous pieces of evidence, albeit of low quality, that appropriate use of monitoring and antagonists of muscle block can positively impact RNB and related morbidity. Already in the Discussion and, therefore, in the commentary editorial and in the numerous other contributions available online, it is emphasized that POPULAR (the first large prospective observational study on the subject) necessarily imposes a critical reflection on current "beliefs," as it raises questions about the adequacy of the TOF-R cutoff at 0.9, despite needing further validation. However, as it stands, quantitative monitoring remains fundamental for guiding reversal, and neither can nor should be abandoned, as their lack of impact on outcomes reported by POPULAR does not necessarily imply that they are incapable of reducing RNB.

In current anesthesiology clinical practice, we have reversal agents for neuromuscular blockers that, together with monitoring, ensure adequate recovery of muscle function at the end of general anesthesia.

Neostigmine, an anticholinesterase that exerts its action by antagonizing the neuromuscular block of all non-depolarizing agents through an indirect mechanism (inhibiting acetylcholinesterase and thereby reducing the metabolism of acetylcholine, whose levels will increase at the neuromuscular junction in such a way as to compete with non-depolarizing blockers for nicotinic receptors), has a ceiling effect, meaning that once acetylcholinesterase is completely inhibited, further doses of the drug do not produce additional effects: for this reason, it cannot be used in cases of deep block. The administration of neostigmine can be performed at a dosage of 50-70 mcg/kg in the presence of at least one response to TOF stimulation, associated with atropine 0.01 mg/kg for anticholinergic/antimuscarinic action. In the case of complete recovery from the block, neostigmine may cause weakness in the genioglossus muscle; secondary side effects due to stimulation of muscarinic receptors include bradycardia, tachycardia, hypotension, bronchospasm, salivation, nausea, vomiting, abdominal cramps, sweating, all adequately countered by the combined administration of atropine. If used as an antagonist of succinylcholine, it may have a synergistic effect and therefore prolong the duration of neuromuscular block.

A revolution in the field of reversal of neuromuscular blockers and clinical anesthetic practice more broadly has been the introduction of sugammadex, a modified cyclodextrin that selectively and rapidly encapsulates aminosteroid non-depolarizing blockers at the plasma level with progressive and rapid elimination from the neuromuscular junction and subsequent renal excretion. According to the SIAARTI Good Clinical Practices, sugammadex can be used to immediately antagonize the block induced by rocuronium at a dosage of 16 mg/kg in cases of deep block (TOF = 0 and PTC ≥ 1). Sugammadex can be administered at a dosage of 4 mg/kg, achieving a recovery of TOF-ratio > 0.9 in about 3 minutes. A dose of 2 mg/kg is useful for antagonizing the block when two responses to TOF stimulation appear. Sugammadex acts more rapidly than neostigmine and has rare side effects. In studies on pediatric patients aged 2 to 17 years, the safety profile of sugammadex (up to 4 mg/kg) was generally similar to that observed in adults.

Objectives

This study reports the results of an Italian investigation conducted to obtain information on current anesthetic

practices regarding the use of neuromuscular blockers, their reversals, and neuromuscular monitoring in pediatric, adult, and pregnant patients. Special attention was given to obtaining data on the type of neuromuscular blocker used, the frequency of neuromuscular monitoring, the TOF Ratio value considered safe for evaluating recovery from neuromuscular blockade, the use of reversals along with their side effects, and the incidence of PORC.

Materials and methods

This study presents the findings of an Italian investigation through SIAATIP - Italian Society of Anesthesia, Analgesia and Pediatric Intensive Care -. A digital questionnaire, distributed via link, social media, and word of mouth, was administered to specialist physicians and those in specialized training in Anesthesia and Intensive Care, and Pain Therapy in Italy. The questionnaire was designed with questions aimed at obtaining information about the clinical practice of neuromuscular blockade, categorized by patient type (adult, pediatric, or pregnant). Respondents were asked to provide details about the type of neuromuscular blocker used, the type of neuromuscular monitoring and associated parameters for extubation, whether and how the relevant values are documented in the anesthesia record, the type of reversal and any side effects encountered, and the incidence of PORC.

Data were collected between February 1, 2023, and March 19, 2024. Responses were collected anonymously. Data were stratified by age, geographic location, and type of workplace (public or private) and were analyzed considering percentage values.

Results

The questionnaire was completed by 287 anesthetists, mainly from central Italy and predominantly (about 40%) with 5 to 10 years of work experience. Most reported working exclusively with adult patients (about 48%), while only 16% and 15% worked with adult and pregnant patients and with adult and pediatric patients, respectively. Even fewer, about 6%, reported working only with pediatric patients (see Table 1).

VARIABLE	VALUE	N° (%)
Number of anesthesiologists	287	--
Years of service	<5	68 (24%)
	5-10	116 (40%)
	>10	103 (36%)
Workplace	Public	266 (93%)
	Private/Private affiliated	21 (7%)
Part of a training network of the specialization school	Yes	178 (62%)
	No	109 (38%)
Medical specialist in training	Yes	20 (7%)
	No	267 (93%)
Anesthesia in	Adult patients	138 (48%)
	Adult and pregnant patients	45 (16%)
	Adult and pediatric patients	42 (15%)
	Adult, pregnant, and pediatric patients	34 (12%)
	Pediatric patients	19 (6%)
	Pediatric and pregnant patients	7 (2%)
	Pregnant patients	2 (1%)

Table 1. Results: General Information

The questionnaire indicates that the most commonly used neuromuscular blocker in adult, pediatric, and pregnant patients is undoubtedly rocuronium, with a percentage exceeding 90% across all three categories.

Adult Patient

About 21% of anesthetists reported always using neuromuscular monitoring in adults (see Table 2), predominantly with acceleromyography-based tools, while a significant 33% indicated that they never use it. Monitoring appears to be more frequently utilized (46%) in relation to patient type (ASA ≥ 2) and procedure type (major surgery). Furthermore, regarding neuromuscular monitoring systems, about 51% expressed that they never use post-tetanic count (PTC) as an intraoperative guide for deep neuromuscular block reversal, while approximately 39% use PTC in relation to patient type (ASA ≥ 2) and procedure type (major surgery). The questionnaire also reveals that, within the adult patient category, it is not neuromuscular monitoring that guides the administration of additional doses of neuromuscular blockers (23%) nor the time elapsed since the last dose (18%), but rather clinical manifestations (56%), such as patient movements or ventilator non-compliance.

Speaking of TOF, there seems to be consensus that, among those using it as a neuromuscular monitoring system, the minimum TOF ratio value for extubation is 0.9 (60%), while 29% do not use the TOF ratio as a guiding parameter for extubation. Another important point to emphasize is the completion of the anesthetic record with values and data from neuromuscular monitoring at the time of extubation: only 23% report this as a common practice, while about 46% of respondents never do it.

Sugammadex appears to be the most commonly used reversal agent in adults (85%), while the depolarizing mixture (neostigmine + atropine) is chosen by only 5% of anesthetists. The remaining percentage stated that they do not use any reversal but wait for spontaneous recovery. The choice of sugammadex dosage seems to be more frequently determined by both the time since the last administration of the neuromuscular blocker and the values from neuromuscular monitoring (42%). Regarding potential side effects of sugammadex, about 72% of participants reported never having encountered any; among the small percentage who did, the most commonly reported side effect was bradycardia.

The data shows that, based on the participants' work experience, the incidence of residual neuromuscular block (PORC) in adult patients is 16%, a certainly non-negligible percentage. Furthermore, residual neuromuscular block in adult patients does not appear to be associated with lower usage of sugammadex: among those who reported using this reversal agent, PORC occurred in 17% of cases compared to 8% in those using alternative reversals to sugammadex or waiting for spontaneous recovery. Postoperative residual neuromuscular block also does not seem to be associated with lower usage of neuromuscular monitoring systems. The data indeed shows that, among those who reported experiencing PORC, 50% always use monitoring systems, 37.5% sometimes depending on the surgical procedure and patient (ASA ≥ 2), while only 12.5% stated that they never use them.

VARIABLE	VALUE	N° (%)
Neuromuscular blocker	Rocuronium, Cisatracurium	248 (97%), 9 (3%)
Neuromuscular monitoring usage	No never, Yes always, Sometimes	84 (33%), 55 (21%), 118 (46%)
Most frequently used neuromuscular monitoring	Acceleromyography, No use, Pressure peaks detection, Kinesiomyography	158 (62%), 81 (31%), 14 (6%), 4 (1%)
Use of PTC as a guide in deep muscle relaxation	No never, Yes always, Sometimes	132 (51%), 26 (10%), 99 (39%)
Guideline for administering NMBA booster doses	Clinical signs, Monitoring, Time since last dose, Surgeon request, No boosters	145 (56%), 58 (23%), 47 (18%), 5 (2%), 2 (1%)
Reversal	Sugammadex, None, Reversal mix	219 (85%), 26 (10%), 12 (5%)
Sugammadex dosage selection based on	Time since last NMBA dose, Monitoring values, Both, Don't use Sugammadex	91 (35%), 30 (12%), 109 (42%), 27 (11%)
Most common Sugammadex side effects	Never observed, Don't use Sugammadex, Bradycardia, Cough, Allergic reactions, Hypotension	185 (72%), 32 (13%), 29 (11%), 6 (2%), 3 (1%), 2 (1%)
Minimum TOF value for extubation	No TOF ratio use, 0.9, 1, 0.8, 0.7	75 (29%), 155 (60%), 18 (7%), 5 (2%), 4 (2%)
Completion of anesthetic record with neuromuscular monitoring data	No never, Yes always, Occasionally	118 (46%), 60 (23%), 79 (31%)
PORC experience	Yes, No	40 (16%), 217 (84%)
Sugammadex in PORC cases	PORC yes, PORC no	37 (17%), 182 (83%)
Reversal mix or spontaneous recovery in PORC	PORC Yes, PORC No	3 (8%), 35 (92%)
PORC Neuromuscular monitoring	Always, Sometimes, Never	20 (50%), 15 (37.5%), 5 (12.5%)

Table 2. Results: Adult Patient

Pregnant Patient

Focusing on the percentage of anesthetists who stated they work with pregnant women (see Table 3), it is evident that most of them have a work experience of over 10 years (about 50%) or between 5 and 10 years (34%). Neuromuscular monitoring does not seem to be a common practice for pregnant patients, as only 20% reported using it routinely, while 41% stated they use it only in relation to the patient (ASA ≥ 2) and the surgical procedure (major surgery), and about 39% never use it. The neuromuscular monitoring system most commonly used for pregnant patients is based on acceleromyography, while for PTC as an intraoperative guide for deep muscle relaxation, only 9% appear to use it consistently.

As with adult patients, the main tool for administering additional doses of neuromuscular blocker during the maintenance of general anesthesia for pregnant patients appears to be clinical assessment (41%), while neuromuscular monitoring (29%) and the time since the last administration (19%) seem to be less frequently utilized references.

The TOF-R is a parameter that is used as a guide for extubation in 54% of pregnant patients, and the value most frequently referenced is almost always 0.9.

Only 29% of participants consistently report neuromuscular monitoring values and data in the anesthetic chart of the pregnant patient at the time of extubation; 45% never report it, while 26% do so occasionally in cases of ASA ≥ 2 patients undergoing major or urgent/emergency surgery.

Sugammadex is confirmed as the first-choice reversal agent (81%), and the dosage is predominantly determined based on the time elapsed since the last administration. Similar to adults, adverse effects following the administration of sugammadex seem to be rare in pregnant patients; bradycardia is again the most frequently reported side effect.

PORC appears to be an infrequent but not rare occurrence in pregnant patients, with a reported percentage of 6%. As in adults, the use of sugammadex does not seem to be associated with a lower risk of PORC.

Data show that anesthetists who reported using sugammadex had experiences of residual curarization in 8% of cases, while those who waited for spontaneous neuromuscular recovery or used a decurarizing mixture did not experience PORC.

We also highlighted that PORC does not seem to be associated with a lower use of neuromuscular monitoring systems.

Data for pregnant patients show that those who reported experiences of PORC always use neuromuscular monitoring in 40% of cases, sometimes in relation to the surgical procedure and the patient (ASA ≥ 2) in 40% of cases, and never in 20% of cases.

VARIABLE	VALUE	N° (%)
Neuromuscular blocker	Rocuronium, Cisatracurium, Other	80 (94%), 2 (2%), 3 (4%)
Neuromuscular monitoring usage	No never, Yes always, Sometimes	33 (39%), 17 (20%), 35 (41%)
Most frequently used neuromuscular monitoring	Acceleromyography, No use, Pressure peaks detection, Kinesiomyography	46 (54%), 33 (39%), 2 (2%), 4 (5%)
Use of PTC as a guide in deep muscle relaxation	No never, Yes always, Sometimes	55 (65%), 8 (9%), 22 (26%)
Guideline for administering NMBA booster doses	Clinical signs, Monitoring, Time since last dose, Surgeon request, No boosters	35 (41%), 25 (29%), 16 (19%), 1 (2%), 8 (9%)
Reversal	Sugammadex, None, Reversal mix	69 (81%), 14 (17%), 2 (2%)
Sugammadex dosage selection based on	Time since last NMBA dose, Monitoring values, Both, Don't use Sugammadex	34 (40%), 18 (21%), 21 (25%), 12 (14%)
Most common Sugammadex side effects	Never observed, Don't use Sugammadex, Bradycardia, Cough, Allergic reactions, Hypotension	60 (71%), 12 (14%), 9 (11%), 1 (1%), 2 (2%), 1 (1%)
Minimum TOF value for extubation	No TOF ratio use, 0.9, 1, 0.8, 0.7	28 (33%), 46 (54%), 6 (7%), 3 (4%), 2 (2%)
Completion of anesthetic record with neuromuscular monitoring data	No never, Yes always, Occasionally	38 (45%), 25 (29%), 22 (26%)
PORC experience	Yes, No	5 (6%), 80 (94%)
Sugammadex in PORC cases	PORC yes, PORC no	5 (8%), 64 (92%)
Reversal mix or spontaneous recovery in PORC	PORC Yes, PORC No	0 (0%), 16 (100%)
PORC Neuromuscular monitoring	Always, Sometimes, Never	2 (40%), 2 (40%), 1 (20%)

Table 3. Results: Pregnant Patient

Pediatric Patient

Moving on to the data regarding pediatric patients (see Table 4), the anesthesiologists who participated in the survey predominantly work with children over 3 years old (57%), and most have work experience between 5 and 10 years (45%). Neuromuscular monitoring appears to be more commonly used in this patient population, as 33% reported always using it, 41% based on the patient's condition (ASA ≥ 2) and the surgical procedure (major surgery), while 26% never use it. Acceleromyography remains the most utilized monitoring system (70%), while PTC as intraoperative guidance for deep neuromuscular block reversal in pediatric patients is rather unusual (only 8% would use it).

According to the data, clinical manifestations are the parameters most relied upon for administering additional doses of neuromuscular blockers during the maintenance of general anesthesia in pediatric patients (43%), while less attention is given to neuromuscular monitoring (32%) or the time elapsed since the last dose (19%).

23% of participants stated they do not use minimum TOF-R for extubating pediatric patients, while among those who do, 56% use a guiding value of 0.9. Most (38%) reported documenting neuromuscular monitoring values and data in the anesthetic record at the time of extubation, while 33% do so sporadically in the case of ASA ≥ 2 patients undergoing major or urgent/emergency surgery.

In pediatric patients, sugammadex remains the most chosen reversal agent for neuromuscular blockers by anesthesiologists (94%), with dosage often chosen based on both neuromuscular monitoring values and the time elapsed since the last administration (53%).

Adverse effects following sugammadex have never been reported by 83% of respondents, while among those who reported experiencing them, bradycardia was the most mentioned.

Anesthesiologists with experience of PORC in pediatric patients represent about 9%, each of whom stated they use sugammadex. In contrast, those using alternative reversals (decurarizing mixtures) or waiting for spontaneous recovery reported never having experienced residual curarization.

This trend is consistent across all three scenarios (adult patient, pregnant patient, and pediatric patient) and suggests that the routine use of sugammadex alone is not sufficient to prevent PORC.

At the same time, it is noteworthy that the experience of PORC does not seem to be linked to the non-use of neuromuscular monitoring systems, even in children.

The data show that 23% of those who reported having experienced PORC always use monitoring systems, while 77% do so sometimes depending on the patient (ASA ≥ 2) and the surgical procedure.

VARIABLE	VALUE	N° (%)
Neuromuscular blocker	Rocuronium, Cisatracurium	104 (99%), 1 (1%)
Neuromuscular monitoring usage	No never, Yes always, Sometimes	27 (26%), 35 (33%), 43 (41%)
Most frequently used neuromuscular monitoring	Acceleromyography, No use, Pressure peaks detection, Kinesiomyography	73 (70%), 27 (26%), 3 (3%), 2 (2%)
Use of PTC as a guide in deep muscle relaxation	No never, Yes always, Sometimes	69 (66%), 8 (8%), 28 (26%)
Guideline for administering NMBA booster doses	Clinical signs, Monitoring, Time since last dose, Surgeon request, No boosters	45 (43%), 34 (32%), 20 (19%), 1 (1%), 5 (5%)
Reversal	Sugammadex, None, Reversal mix	99 (94%), 4 (4%), 2 (2%)
Sugammadex dosage selection based on	Time since last NMBA dose, Monitoring values, Both, Don't use Sugammadex	27 (26%), 20 (19%), 56 (53%), 2 (2%)
Most common Sugammadex side effects	Never observed, Don't use Sugammadex, Bradycardia, Cough, Bronchospasm	87 (83%), 3 (3%), 13 (12%), 1 (1%), 1 (1%)
Minimum TOF value for extubation	No TOF ratio use, 0.9, 1, 0.8, 0.7	24 (23%), 59 (56%), 18 (17%), 3 (3%), 1 (1%)
Completion of anesthetic record with neuromuscular monitoring data	No never, Yes always, Occasionally	30 (29%), 40 (38%), 35 (33%)
PORC experience	Yes, No	9 (9%), 96 (91%)
Sugammadex in PORC cases	PORC yes, PORC no	9 (9%), 96 (91%)
Reversal mix or spontaneous recovery in PORC	PORC Yes, PORC No	0 (0%), 6 (100%)

Table 4. Results: Pediatric Patient

Seniority of Service

We then continued with the analysis, attempting to compare some key data across the three scenarios considered.

In the context of choosing to use neuromuscular monitoring for adults (see Table 5), among anesthesiologists with more than 10 years of service, 24.3% reported always using it, while 41.7% resorted to it only based on the type of patient (ASA ≥ 2) and the surgical procedure (major surgery). In contrast, the younger anesthesiologists with less than 5 years of service routinely use TOF in 23.9% of cases, while in relation to the type of patient and surgical procedure, the percentage is 38.8%.

The trend is similar in pregnant patients (see Table 6) where anesthesiologists with more than 10 years of service, 16.7 % reported always using it, while 45.7% resorted to it only based on the type of surgical procedure. Younger anesthesiologists with less than 5 years of service routinely use TOF in 28.6 % of cases, while in relation to the type of patient and surgical procedure, the percentage is 21.4%.

This trend seems to change when it comes to children (see Table 7): physicians with more than 10 years of service always use neuromuscular monitoring in 11.5% of cases, never in 38.5%, and sometimes in 50%. Those with less

than 5 years of service, however, always use it in 32.3%, never in 42%, and sometimes in 22.6%.

VARIABLE	VALUE	N° (%)
Years of service < 5 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		16 (23.9%), 26 (38.8%), 24 (35.8%)
Years of service between 5 and 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		13 (11.2%), 48 (41.4%), 36 (31.4%)
Years of service > 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		25 (24.3%), 43 (41.7%), 24 (23.3%)

Table 5. Results: Neuromuscular Monitoring in Adult Patients by Years of Service.

VARIABLE	VALUE	N° (%)
Years of service < 5 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		4 (28.6%), 3 (21.4%), 7 (50%)
Years of service between 5 and 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		6 (20.7%), 13 (44.9%), 10 (34.5%)
Years of service > 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		7 (16.7%), 19 (45.2%), 16 (38.1%)

Table 6. Results: Neuromuscular Monitoring in Pregnant Women by Years of Service

VARIABLE	VALUE	N° (%)
Years of service < 5 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		10 (32.3%), 7 (22.6%), 13 (41.9%)
Years of service between 5 and 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		22 (46.8%), 22 (46.8%), 3 (6.4%)
Years of service > 10 years	Neuromuscular monitoring	Yes always, Sometimes, No never
		3 (11.5%), 13 (50%), 10 (38.5%)

Table 7. Results: Neuromuscular Monitoring in Pediatric Patients by Years of Service

Type of Public/Private-Convened Center

Subsequently, we evaluated whether and how working in a public center or in a private/private-convened center could impact the routine use of sugammadex in adult patients (see Table 8). It emerged that 90% of anesthetists working in a public center use sugammadex, 7% wait for spontaneous recovery, and 3% resort to a neuromuscular blocking mixture. In contrast, those working in private or private-convened centers reported waiting for spontaneous neuromuscular recovery in 33% of cases, using sugammadex in 52%, and a neuromuscular blocking mixture in 14% of cases. Despite the small sample we have regarding private centers, it is evident that the use of sugammadex is significantly lower compared to the public counterparts examined.

In private centers, waiting for spontaneous neuromuscular recovery seems to be more common than resorting to medications. We could attempt to explain these differing choices by advancing several hypotheses, primarily focused on economic factors, as sugammadex is not a cost-effective drug. However, more data is needed to process and analyze in order to reach a plausible and certain conclusion on this matter.

VARIABLE	VALUE	N° (%)
Public center	Sugammadex, Reversal mix, Spontaneous recovery	239 (90%), 9 (3%), 18 (7%)
Private/contracted private center	Sugammadex, Reversal mix, Spontaneous recovery	11 (52%), 3 (14%), 7 (33%)

Table 8. Results: Type of Reversal in Adult Patients by Type of Center (Public or Private/Contracted Private)

Type of center: headquarters or not of a training network for specialization schools

An additional analysis was conducted comparing centers that are part of a training network for specialization schools with those that are not. We observed that anesthesiologists working in centers that are part of a training network for specialization schools make greater use of neuromuscular monitoring systems in adult patients compared to their counterparts: 48% reported using it mainly in relation to the procedure (major surgery) and the type of patient (ASA≥ 2), and 25% reported using it routinely; only 27% indicated they do not use it. In contrast, physicians working in centers not affiliated with a training network reported always using neuromuscular monitoring only 15% of the time, never using it 43% of the time, and using it based on the surgical procedure (major surgery) and the patient (ASA≥ 2) 42% of the time.

In this regard, we also highlighted that about 24% of the first group do not use TOF ratio to proceed with the safe extubation of the patient, while in the second group, the percentage is higher, around 36%. Sixty-three percent of

anesthesiologists working in centers that are part of a training network use a TOF ratio value of 0.9 (as per guidelines) as a reference for extubation, while in the counterpart, this percentage is about 50%.

This could be attributed to the training setting for new specialists: anesthesiologists associated with centers in training networks seem to be more attentive to neuromuscular monitoring and myoresolution according to the guidelines.

VARIABLE	VALUE	N° (%)
Center belonging to the training network of the residency school	Neuromuscular monitoring	Yes always, Sometimes, No never
		45 (25%), 85 (48%), 48 (27%)
Center not belonging to the training network of the residency school	Neuromuscular monitoring	Yes always, Sometimes, No never
		16 (15%), 46 (42%), 47 (43%)

Table 9. Results: Neuromuscular Monitoring in Adult Patients by Type of Center (Belonging or Not to the Training Network of the Residency School)

Discussion

Despite dissemination through direct links, social channels, and word of mouth, only 267 structured anesthetists responded to the questionnaire in just over a year, against an estimated number of 12,819 in the country for 2023 (Source: SUMAI Assoprof Study Center, data processed by FNOMCeO and ISTAT). The low response rate of 2% may further indicate the uneven clinical practice in managing proper neuromuscular resolution, as well as a possible lack of interest among professionals in engaging in discussions about such a controversial yet relevant topic.

The heterogeneity in our data primarily concerns the management of neuromuscular monitoring in all its aspects. While there is agreement on the type of neuromuscular blocker and reversal agent most commonly used in adults, children, and pregnant women—specifically, rocuronium and sugammadex—there is a notable limited use of neuromuscular monitoring tools, despite them being the only means to objectively measure the level of neuromuscular blockade. Neuromuscular monitoring is mainly employed concerning the patient's clinical conditions (ASA ≥ 2) or the type of surgery (major surgery).

The data collected from this survey indicate that the routine use of neuromuscular monitoring is not very common across the three categories of patients examined. Another important point is that clinical manifestations (ventilator maladaptation, patient movements) primarily guide the administration of additional doses of neuromuscular blockers.

Most anesthetists, whether treating adults, children, or pregnant women, report relying mainly on clinical signs to assess recovery from neuromuscular blockade. The immediate consequence of this behavior is the discharge of a significant number of patients from the operating room with incomplete neuromuscular recovery, leading to various negative outcomes. Postoperative residual curarization (PORC), although infrequent, remains a clinically significant event, as evidenced by the data collected from the questionnaire.

Sixteen percent of anesthetists report having experienced PORC in adult patients, 6% in pregnant patients, and 9% in pediatric patients. PORC does not seem to correlate with lesser use of neuromuscular monitoring systems or sugammadex, confirming that both should be utilized correctly according to guidelines, in terms of dosage and TOF-R value; considering the limited sample size, this phenomenon might be attributed to anesthetists who do not use neuromuscular monitoring and sugammadex potentially being less vigilant in identifying not particularly severe cases of PORC.

Randomized controlled trials and observational studies have reported a lower incidence of residual neuromuscular blockade with quantitative monitoring compared to qualitative assessment or clinical evaluation alone. Quantitative intraoperative monitoring of the degree of neuromuscular blockade is essential during induction, surgical phases, and extubation. It helps reduce complications during recovery and allows for the correct timing and dosing of sugammadex.

Recent literature on PORC aligns with our findings. It is evident that raising the minimum TOF ratio threshold to

0.9 has reduced the incidence of residual curarization. However, studies published since 2000 show incidence rates ranging from 4% to 57%. In a large survey involving European and American anesthetists, about 80% reported never having seen clinically significant residual paralysis, while 60% estimated the incidence to be less than 1%. There is undoubtedly a discrepancy between the estimated current incidence of PORC and what practitioners perceive and report, as also observed in our study's percentages. This could be explained by the fact that not all respiratory complications observed in the recovery room or ward can be attributed to neuromuscular blockade.

Furthermore, PORC may go unnoticed initially, leading to delayed consequences once the patient is no longer under the anesthetist's direct supervision. For example, residual paralysis could result in symptoms like muscle weakness and delayed discharge from the recovery room. One study highlighted the role of residual curarization in postoperative respiratory complications. In examining 7,459 patients, it was found that the TOF-R measured in patients with respiratory complications was 0.62, compared to 0.98 in patients without complications. A TOF ratio greater than 0.9 was observed in only 9.5% of patients with respiratory complications. Thus, a significant percentage of respiratory complications (upper airway obstructions and/or hypoxemia) may be attributed to residual neuromuscular blockade.

PORC, as our data also indicate, is an iatrogenic condition that is not so rare, affecting up to one-third of patients undergoing general anesthesia with neuromuscular blockers. To prevent and limit its incidence, it is essential to employ neuromuscular monitoring throughout the duration of anesthesia.

Integrating the data on years of service and the use of neuromuscular monitoring reveals no significant differences for adult patients, while in pediatric cases, less experienced anesthetists seem to be more attentive.

There also appears to be no substantial difference in the choice to use monitoring based on patient type. In adults, as well as in children and pregnant women, anesthetists seem to decide on neuromuscular monitoring primarily based on the patient's comorbidities (ASA score) and the type of surgery rather than other factors.

Another interesting data point, where responses were uniform across the three scenarios and consistent with guidelines, relates to the minimum TOF ratio value for extubation. Confirmation of a TOF-R ratio of 0.9 appears to mitigate the risk of residual neuromuscular blockade and serves as a pass for safe extubation.

A result not aligned with the Good Clinical Practice guidelines from SIAARTI is the importance of recording the values and data obtained from neuromuscular monitoring during all phases of the surgical procedure, particularly at extubation and/or discharge from the operating room. The percentages from our data show that this measure is primarily observed in pediatric patients, while for adults and pregnant women, the trend is to report values only in specific scenarios (patients in complex clinical conditions or surgical procedures).

Monitoring of PTC as a guide for maintaining intraoperative neuromuscular resolution is not used in more than 60% of cases, for adult, pregnant, and pediatric patients: this could negatively impact splanchnic organs during laparoscopic surgery if surgeons need to use high pneumoperitoneum pressures.

Given the limited sample size, our data suggest a reduced use of sugammadex in private or private-contracted centers for adult patients compared to public centers, with a significant number of professionals reporting they wait for spontaneous muscle recovery. This may be due to purely economic choices considering the cost of reversals.

We observed that anesthetists working in centers affiliated with residency programs make greater use of neuromuscular monitoring systems in adult patients: 48% reported using it primarily related to the procedure (major surgery) and the type of patient (ASA $\geq$ 2), and 25% use it daily; only 27% stated they do not use it. More than half of anesthetists working in residency program centers

use a TOF ratio of 0.9 as a reference for extubation (as per guidelines), while the corresponding percentage is about 50% in non-affiliated centers. Anesthetists in training networks appear to be more attentive to managing neuromuscular resolution according to guidelines.

The overall insensitivity of specialists to issues related to neuromuscular resolution and monitoring seems widespread. In a 2012 survey conducted on about 1,500 specialists in Italy, it was highlighted that most anesthetists still rely on clinical signs of recovery (effectively underestimating their unreliability); only 50% routinely use TOF, and just over 30% correctly indicate a TOF-R ≥ 0.9 to safely proceed with extubation.

It's worth recalling that even in 2009, the "Manual for Safety in the Operating Room: Recommendations and Checklist" from the Ministry of Health reiterated that "neuromuscular transmission monitoring must always be available" in the operating room.

In June 2019, a survey published in the prestigious journal Anesthesia & Analgesia, the official journal of the International Anesthesia Research Society, highlighted a concerning "overconfidence" in monitoring neuromuscular blockade: "overconfidence" was present in 92% of respondents, compared to less than 60% of correct responses (approximately 1,600 anesthetists from over 80 countries participated), a percentage described as "pure conjecture" or, as the authors humorously noted, akin to "coin tossing." The overestimation of personal abilities and skills contributes to the belief that neuromuscular blockade can be managed "intuitively," even doing away with conventional peripheral nerve stimulation. Thus, there exists a massive barrier to the routine implementation of optimal quantitative monitoring—a genuine "cultural resistance" to necessary change. In the editorial commentary on the survey, it was noted that numerous other barriers exist, such as the time required for necessary calibration of the monitoring device, the relative difficulty of using it with covered limbs, and more generally, the perception of its purchase and maintenance costs.

Conclusions

The most important role of scientific societies is not only in training but also in serving as a central reference for the pursuit of good clinical practices, recommendations, and guidelines. This task is not only challenging but often subjected to critical analysis, especially considering the vast amount of documents produced, sometimes lengthy texts with references to foreign literature that are not always easily applicable to Italian clinical practices.

For a scientific society to issue references and guidelines to its members, it is essential to start from the members themselves. It is necessary first to understand what behaviors, procedures, techniques, and so on healthcare personnel apply in daily clinical practice on a national or international basis in order to thoroughly analyze the strengths and weaknesses and draw the necessary corrections from which to derive a guiding document aimed at the safety and effectiveness of the provided care, along with the correctness of the procedures used by anesthesiologists.

One of the most useful and rapid tools for conducting this analysis is represented by surveys. It is precisely through a survey that we have decided to deeply analyze the experience of anesthesiologists regarding the neuromuscular blockade and reversal of pediatric patients compared to adult patients. This is also in light of the use of neuromuscular blockers that require reversal and the correct use of them alongside specific monitoring. Equally important is the knowledge of specific dosages in pediatric age, especially in those hospital structures where pediatric anesthesia is occasional or where specific competencies are lacking or deficient.

The data obtained from the national questionnaire confirm the heterogeneity of clinical practice in the management of neuromuscular blockade, along with all the resulting issues. Despite a response rate of only 2% to the national questionnaire, likely due to a possible lack of interest from professionals in discussing such a controversial yet relevant topic, the obtained data are nonetheless in line with national and international literature.

They show that:

- Rocuronium and sugammadex are, respectively, the most frequently used neuromuscular blocker and reversal agent; among the rare side effects of sugammadex observed, bradycardia stands out for its frequency.
- Neuromuscular monitoring is not frequently used routinely but mainly in relation to the type of patient (ASA ≥ 2) and the type of procedure (major surgery), in adults, children, and pregnant women.
- The type of neuromuscular monitoring most commonly used is that based on acceleromyography, in adults, children, and pregnant women.
- Monitoring of PTC as a guide for maintaining neuromuscular blockade intraoperatively is never used in more than half of the cases, whether for adult, pregnant, or pediatric patients, with a possible negative impact during laparoscopic surgery.
- Clinical manifestations (ventilator intolerance, patient movements) are the most frequently used guiding elements for any administration of additional doses of intraoperative neuromuscular blockers.
- Most anesthesiologists, both in adults and in children or pregnant women, report relying mainly on clinical signs to assess recovery from neuromuscular blockade.
- Among those who use neuromuscular monitoring to manage recovery from blockade, just over half consider TOF-R = 0.9 as the cutoff for safe extubation.
- Among users of sugammadex, the majority report using it primarily based on neuromuscular monitoring and the time elapsed since the last administration of rocuronium.
- More than 45% of anesthesiologists report not documenting neuromuscular monitoring data for adult and pregnant patients. However, in pediatric patients, this percentage drops to 29%.
- 16% of anesthesiologists report having experienced PORC (Postoperative Residual Curarization) with adult patients, 6% with pregnant patients, and 9% with pediatric patients. PORC does not seem to be associated with less use of neuromuscular monitoring systems or sugammadex, confirming that both should be used correctly according to guidelines, in terms of dosage and TOF-R value.
- In choosing whether to use neuromuscular monitoring, seniority does not appear to be a decisive factor for adult patients, while in pediatric patients, less experienced anesthesiologists seem to be more attentive.
- Anesthesiologists working in training centers for specialty schools seem to use neuromuscular monitoring systems more frequently in adult patients compared to their counterparts (73% vs. 57%). A TOF-R cutoff of 0.9 is considered safe by 63% of anesthesiologists employed in training centers, compared to 50% of their counterparts.
- Consistent with the small sample size obtained, there is a reduced use of sugammadex in private or privately-contracted centers for adult patients compared to public centers, with a significant portion of professionals reporting that they wait for spontaneous muscle recovery. This may be due to purely economic considerations given the cost of reversals.

The use of neuromuscular blockers is an essential and indispensable component of general anesthesia; good clinical practice necessarily requires monitoring the effects of these drugs and the effectiveness of their reversal, or else the life of the patient may be jeopardized.

References

1. Reversal of Neuromuscular Blocking Agents in Patients Undergoing General Anaesthesia (REVEAL Study). Massimiliano Greco, Pier Francesco Caruso, Giovanni Angelotti, Romina Aceto et al. J. Clin. Med. 2023.
2. Buone pratiche cliniche SIIARTI: Miorisoluzione, monitoraggio neuromuscolare e antagonismo.
3. Fuchs-Buder T, Romero CS, Lewald H, Lamperti M, Afshari A, Hristovska AM, Schmartz D, Hinkelbein J, Longrois D, Popp M, de Boer HD, Sorbello M, Jankovic R, Kranke P. Peri-operative management of neuromuscular blockade: A guideline from the European Society of Anaesthesiology and Intensive Care. Eur J Anaesthesiol. 2023 Feb 1;4.

4. Pharmacology of Neuromuscular Blocking Drugs. Mohamed Naguib, Cynthia A., Lien Claude Meistelman; Continuing Education in Anaesthesia, Critical Care & Pain | Volume 4 Number 1 2004).
5. Guidelines on muscle relaxants and reversal in anaesthesia. Christophe Baillard, Jean-Louis Bourgain, Gaëlle Bouroche, Laetitia Desplanque et al. Anaesth Crit Care Pain Med. 2020 Feb.
6. American Society of Anesthesiologists Practice Guidelines 2023 for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade Stephan R. Thilen, M.D., M.S. (co-president); Wade A. Weigel, M.D. (co-president); Michael M. Todd, M.D.; Richard P. Dutton, M.D., M.B.A.; Cynthia A. Lien, M.D.; Stuart A. Grant, M.D.; Joseph W. Szokol, M.D., J.D., M.B.A., FASA; Lars I. Eriksson, M.D., Ph.D., FRCA; Myron Yaster, M.D.; Mark D. Grant, M.D., Ph.D.; Anesthesiology January 2023, vol. 138, 13–41.
7. Buone pratiche cliniche SIAATIP. Sugammadex: reversal del blocco neuromuscolare nel paziente pediatrico.
8. Bulka CM, Terekhov MA, Martin BJ, et al. Non depolarizing Neuromuscular Blocking Agents, Reversal, and Risk of Postoperative Pneumonia. Anesthesiology. 2016;125(4):647-55).
9. POstanaesthesia PULmonary complications After the use of muscle Relaxants in Europe: an international prospective cohort study), iniziato nel 2014 con il patrocinio dell'European Society of Anaesthesiology (Fagerlund MJ, Fink H, Baumüller E, et al. Postanaesthesia pulmonary complications after use of muscle relaxants in Europe: Study protocol of the POPULAR study. Eur J Anaes thesiol. 2016;33(5):381-3.).
10. Kirmeier E, Eriksson LI, Lewald H, et al; POPULAR Contributors. Post-anaesthesia pulmonary complications after use of muscle relaxants (POPULAR): a multicentre, prospec tive observational study. Lancet Respir Med. 2019;7(2):129-40).
11. (Ball L, de Abreu MG, Schultz MJ, Pelosi P. Neuromuscular blocking agents and postoperative pulmonary complications. Lancet Respir Med. 2019;7(2):102-3)
12. Intraoperative acceleromyographic monitoring reduces the risk of residual neuromuscular blockade and adverse respiratory events in the postanesthesia care unit. Murphy GS, Szokol JW, Marymont JH, Greenberg SB, Avram MJ, Vender JS, Nisman M. Anesthesiology 2008; 109:389–98.
13. Intraoperative acceleromyography monitoring reduces symptoms of muscle weakness and improves quality of recovery in the early postoperative period. Murphy GS, Szokol JW, Avram MJ, Greenberg SB, Marymont JH, Vender JS, Gray J, Landry E, Gupta DK. Anestesiologia 2011; 115:946–54.
14. The association between residual neuromuscular blockade (RNMB) and critical respiratory events: a prospective cohort study. Alenezi FK, Alnababtah K, Alqahtani MM, Olayan L, Alharbi M. Perioper Med (Lond) 2021.
15. Usefulness of intra-operative neuromuscular blockade monitoring and reversal agents for postoperative residual neuromuscular blockade: a retrospective observational study. Domenech G, Kampel MA, Garcia Guzzo ME, Novas DS, Terrasa SA, Fornari GG. BMC Anestesio 2019.
16. Residual paralysis: a real problem or did we invent a new disease? Donati F. Can J Anesth 2013;60:714–29.
17. Residual neuromuscular block: Lessons unlearned. Part I: definitions, incidence, and adverse physiologic effects of neuromuscular block. Murphy GS , Brull SJ . Anesth Analg 2010; 111: 120-8.
18. Postoperative residual curarization from intermediate-acting neuromuscular blocking agents delays recovery room discharge. Butterly A, Bittner EA, George E, et al. Br J Anaesth 2010; 105: 304-9.

19. Residual neuromuscular blockade and critical respiratory events in the postanesthesia care unit. Murphy GS, Szokol JW, Marymont JH, Greenberg SB, Avram MJ, Vender JSAnesth Analg 2008; 107: 130-7.
20. Della Rocca G, Iannuccelli F, Pompei L, et al. Neuromuscular block in Italy: a survey of current management. Minerva Anestesiol. 2012; 78(7):767-73.
21. Ministero della Salute (http://www.salute.gov.it/imgs/C_17_pubblicazioni_1119_allegato.pdf).
22. Naguib M, Brull SJ, Hunter JM, et al. Anesthesiologists' Overconfidence in Their Perceived Knowledge of Neuromuscular Monitoring and Its Relevance to All Aspects of Medical Practice: An International Survey. Anesth Analg. 2019;128(6):1118-26.
23. Harman A, Tung A, Fox C, Lien CA. Heuristics, Overconfidence, and Experience: Impact on Monitoring Depth of Neuromuscular Block ade. Anesth Analg. 2019;128(6):1057-59.