HOW TO IMPLEMENT QUANTITATIVE NEUROMUSCULAR MONITORING INTO YOUR PRACTICE

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Disclosures

- Merck-funded research (funds to Mayo Clinic)
- Speaker for Senzime AB

To Do…

- Why should I care about monitoring?
- Recent advances in objective neuromuscular monitoring modalities
- Anesthesia 101: Monitoring Sites/ Patterns of Neurostimulation
- Practical considerations for introducing objective neuromuscular monitors into practice

Consequences of Residual NMB

- Subjectively worse recovery
  Murphy *Anesthesiology* 2011, Murphy *A&A* 2013, Murphy
- Hypoxemia
  Murphy *A&A* 2008
- Impaired Pulmonary Function
  Eikermann *Chest* 2005
- Upper airway obstruction
  Sundman *Anesthesiology* 2000, Murphy *A&A* 2008
- Postop pneumonia
  Berg *Acta Anaesthesiol Scand* 1997
- Respiratory failure
  McLean *Anesthesiology* 2015

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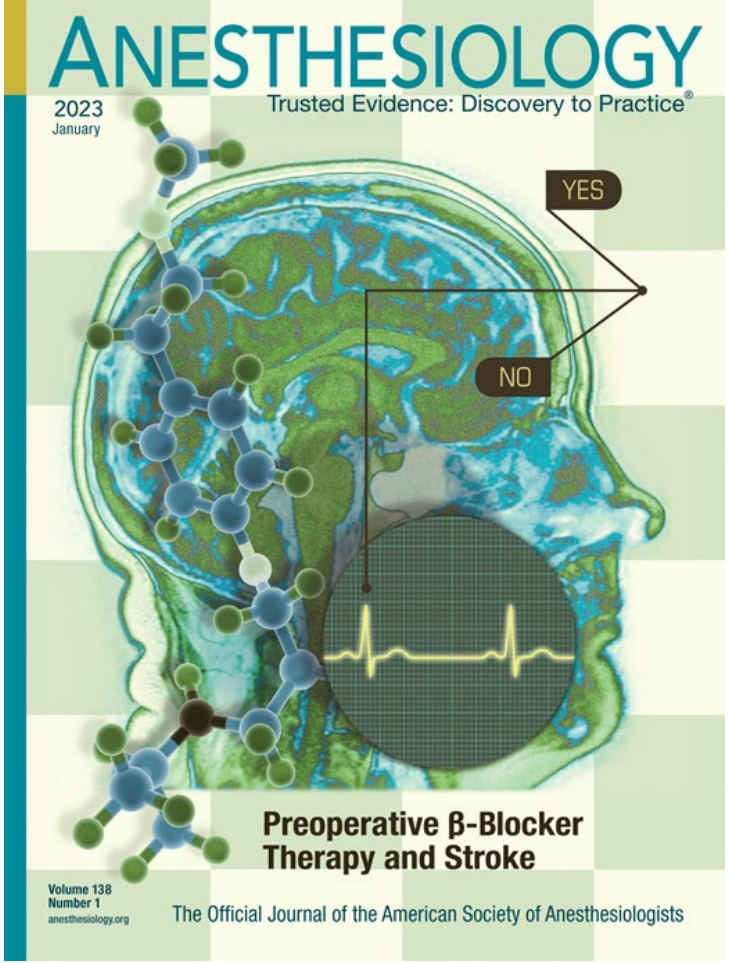
Nomenclature

- Clinical assessment = 5 –sec head lift, grip strength, etc…
- Subjective evaluation = Peripheral nerve stimulator (PNS)
- Quantitative (objective) monitoring = monitor that stimulates a peripheral nerve, measures the response to stimulation, and converts this signal to objective data



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

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Anesthesiology 2023; 138:13–41

Recommendation	Strength of Recommendation	Strength of Evidence
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

Clinical Assessment

Table 3. Diagnostic Attributes of the Clinical Tests; Sensitivity, Specificity, Positive and Negative Predictive Values of an Individual Clinical Test for a Train-of-Four <90%

Variable	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Inability to smile	0.29	0.80	0.47	0.64
Inability to swallow	0.21	0.85	0.47	0.63
Inability to speak	0.29	0.80	0.47	0.64
General weakness	0.35	0.78	0.51	0.66
Inability to lift head for 5 s	0.19	0.88	0.51	0.64
Inability to lift leg for 5 s	0.25	0.84	0.50	0.64
Inability to sustained hand grip for 5 s	0.18	0.89	0.51	0.63
Inability to perform sustained tongue depressor test	0.22	0.88	0.52	0.64

The sensitivity of a test is the number of true positives divided by the sum of true positives + false negatives; the specificity is the number of true negatives divided by the sum of true negatives + false positives. True positives are patients scoring positive for a test and having a train-of-four (TOF) <90%. False negatives are patients with a negative test result but a TOF <90%. True negatives have a negative test score and a TOF not <90%; false positives score positively but have a TOF not <90%. A *positive* test result means *inability* to smile, swallow and speak, general muscular weakness, etc.

Cammu G, et al. Anesth Analg. 2006 Feb;102(2):426-9.

Recommendation	Strength of Recommendation	Strength of Evidence
2. We recommend quantitative monitoring over qualitative assessment to avoid residual neuromuscular blockade.	Strong	Moderate

Peripheral Nerve Stimulator

Cannot reliably detect fade when TOFR > 0.4

- RD Miller *Anesthesiology* 1985
- SJ Brull *A&A* 1993
- Capron *A&A* 2006

Trouble counting twitches

- 50 patients, 666 neurostimulations
- Overestimated twitch count 47% of the time
- Subjective evaluations were higher than objective 92% of the time (95% CI, 87 to 95; P < 0.001)

Renew JR, et al. Can J Anaesth. 2023 May;70(5):878-885.

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

The Ideal Monitor

- Easy to setup/intuitive
- Cost effective
- Portable
- Integrates into EMR
- Adds value during all phases of perioperative care
- Works in a variety of settings (ICU)

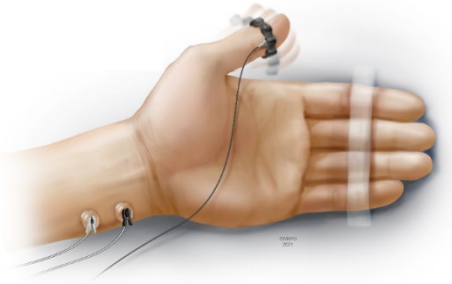
Mechanomyography

- Historic gold standard
- Measures force of isometric contractions
- Force is converted to electrical signal

Brull SJ, Murphy GS. Anesth Analg 111; 129-40, 2010

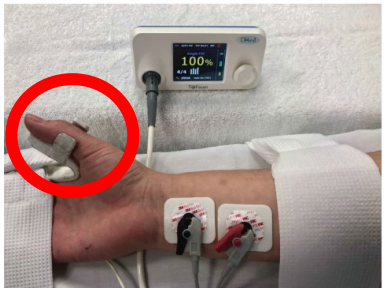
Acceleromyography (AMG)

- Most frequently studied
- Measures acceleration (requires freely moving thumb)
- Can use ECG leads
- “Reverse fade”- baseline TOFR > 100%
- “Staircase phenomenon” – repetitive stimulation increases amplitude of muscle contraction (ST stimulation)



AMG

- 3D transducers can measure complex movement of thumb
- First modality to incorporate Bluetooth connectivity
- Recent efforts demonstrated good level of agreements
- Calibration, normalization, and preload application improved agreement



Murphy GS, et al. Anesthesiology. 2018 Nov;129(5):880-888.

Recommendation	Strength of Recommendation	Strength of Evidence
4. We recommend using the adductor pollicis muscle for neuromuscular monitoring.	Strong	Moderate

Can I still tuck the arms?

Do I have to calibrate?

What about normalization?

@ Extubation $\frac{90\%}{119\%} \approx 74\%$

@ Baseline

$$119\% \times 0.9 \approx 108\%$$

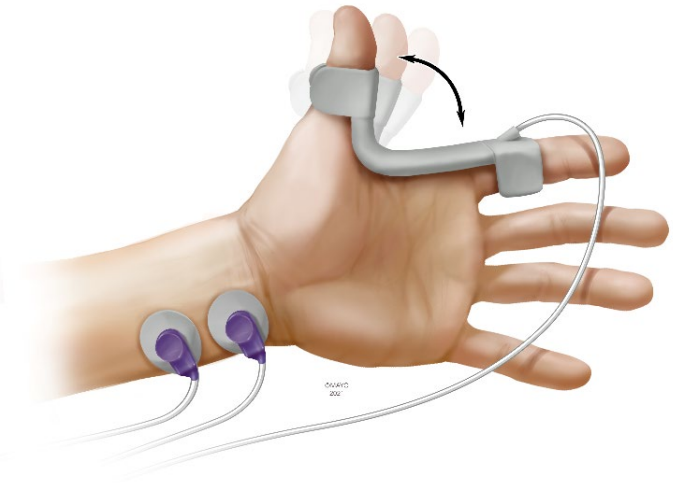
Normalization Matters

- Bias between AMG devices is less with normalization
- Bias between AMG and EMG is less with normalization
- POPULAR study
  - Utilized mostly uncalibrated, non-normalized AMG
- Post hoc analysis demonstrated raising threshold for recovery to TOFR > 0.95 did reduce PPC

Murphy GS, et al. Anesthesiology. 2018 Nov;129(5):880-888.
Nemes R, et al. Anesthesiology 2021 Oct 1;135(4):597-611.
Kirmeier E, et al. Lancet Respir Med. 2019 Feb;7(2):129-140.
Blobner M, et al. Br J Anaesth. 2020 Jan;124(1):63-72.

Kinemyography (KMG)

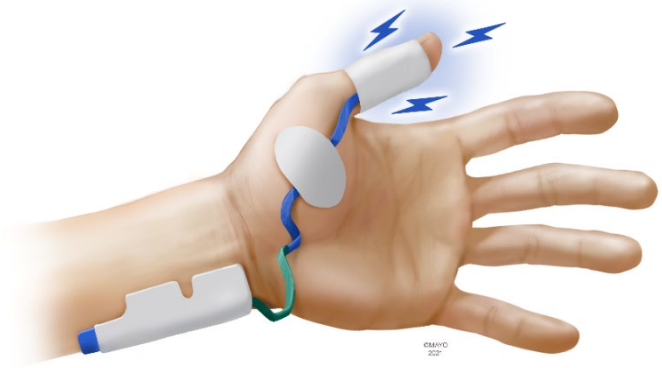
- Similar to AMG
- Measures degree of bend of piezoelectric sensor
- Large bias and wide limits of agreement
- Not associated with reverse fade



Khandkar C,et al. Anaesth Intensive Care. 2016;44:745–751.
Motamed C, et al. Eur J Anaesthesiol. 2003;20:467–469.

Electromyography (EMG)

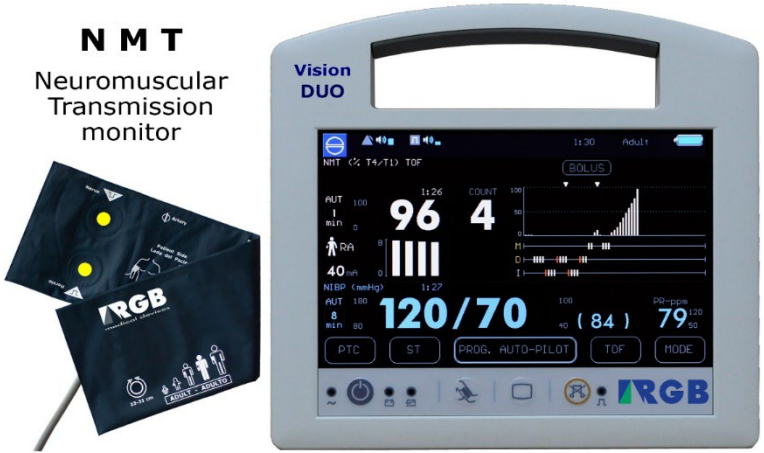
- Measures action potentials (electrical activity) of muscle after neurostimulation
- Does not require freely moving limbs
- Consistent responses over time and not susceptible to changes in myofibril contractility like AMG
- Results comparable to MMG



Hemmerling TM. Can J Anesth 54;58-72, 2007.

Modified Cuff Technique

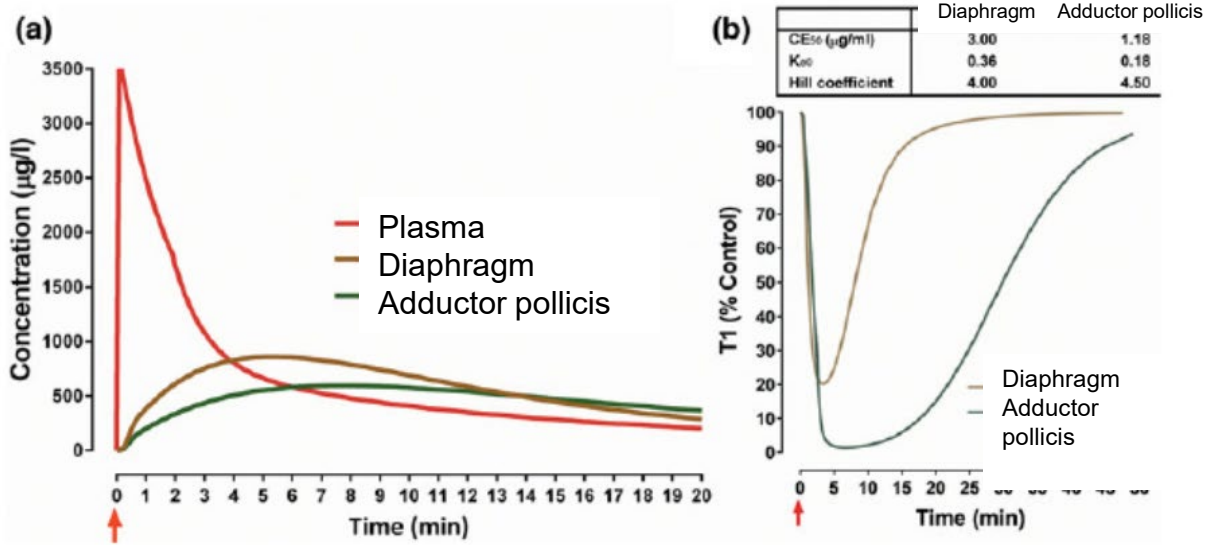
- Integrated into BP cuff
- Stimulates brachial plexus and integrated sensors quantifies pressure changes of the cuff



Monitoring Sites

- Diaphragm
- Hand (AP, ADM, FDI)
- Face (CS, OO)
- Foot (FHB)

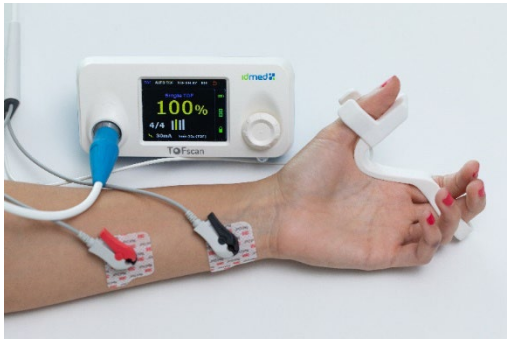
The Diaphragm



Sheiner LB, et al. Clin Pharmacol Ther. 1979 Mar;25(3):358-71

Recommendation	Strength of Recommendation	Strength of Evidence
5. We recommend against using eye muscles for neuromuscular monitoring.	Strong	Moderate

The Hand

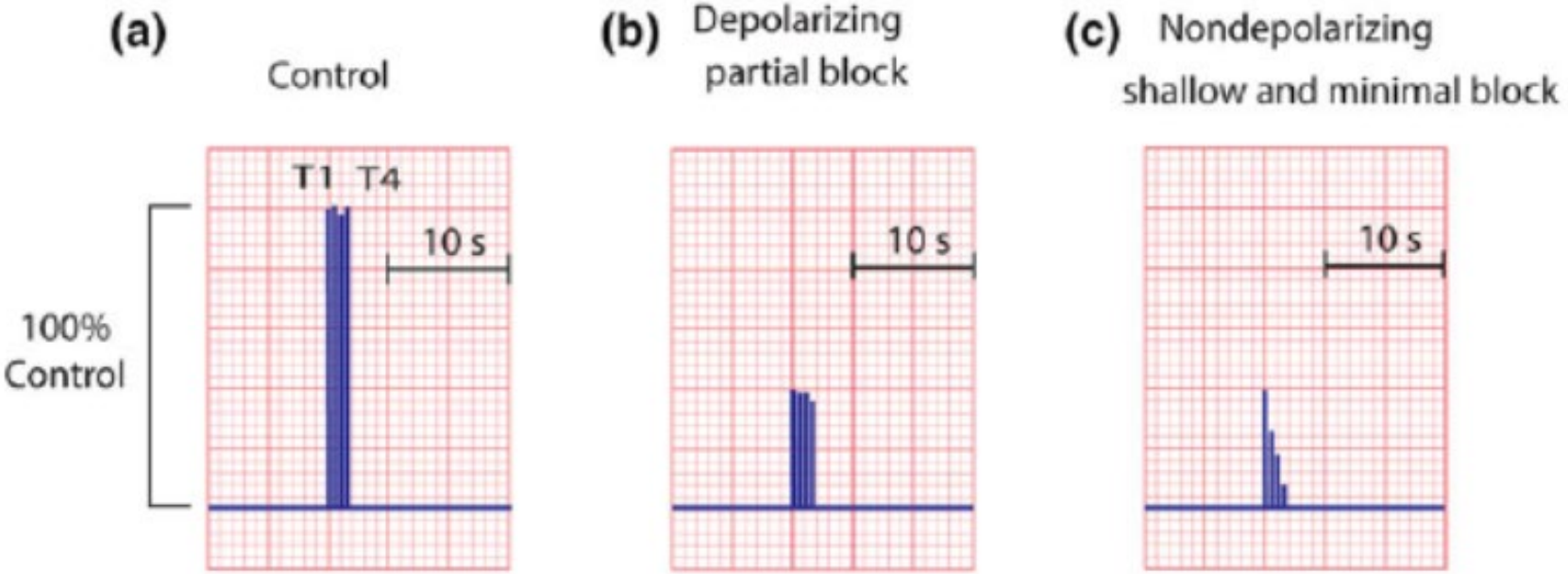


Renew JR, et al. Anesth Analg. 2021 May 1;132(5):1421-1428.
Bowdle A, et al. Anaesthesia. 2020 Feb;75(2):187-195

Patterns of Neurostimulation

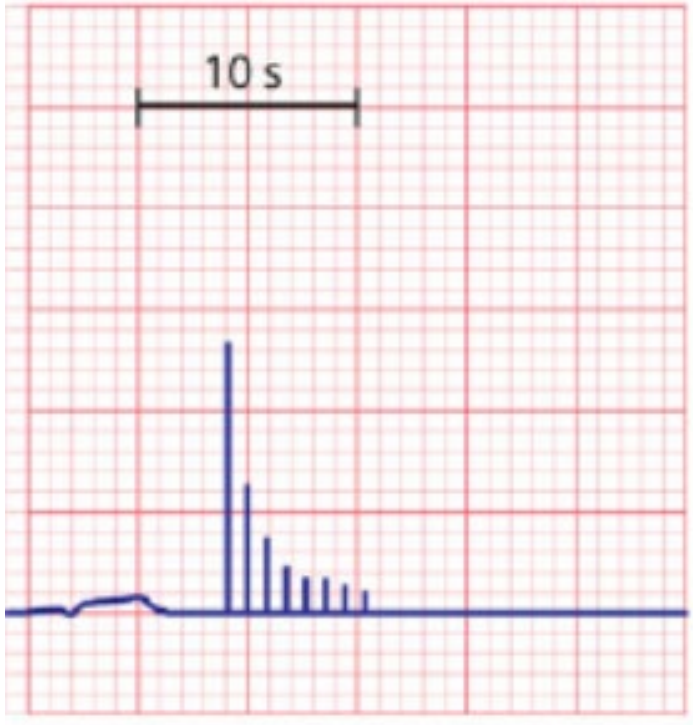
- ~~Single Twitch~~
- Train-of-four
- ~~Double burst stimulation~~
- Post-tetanic count

Train of Four



Naguib M, et al. Anaesthesia. 2017 Jan;72 Suppl 1:16-37

Post-Tetanic Count

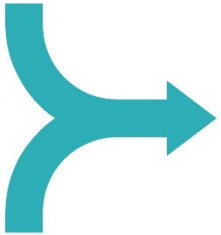


PTC_{AP}		TOF_{CSC}	
Number of twitches	**Time to recovery (min)**	**Number of responses**	**Time to recovery (min)**
1	24 (8)*	1	33 (9)
<5	29 (9)	2	38 (11)
<10	34 (7)	3	44 (9)
>10	39 (9)	4	52 (10)

Naguib M, Brull SJ, Johnson KB. 2017 Jan;72 Suppl 1:16-37.
Dhonneur G, et al. Br J Anaesth. 2007 Sep;99(3):376-9.

Recommendation	Strength of Recommendation	Strength of Evidence
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
7. We suggest neostigmine as a reasonable alternative to sugammadex at minimal depth of neuromuscular blockade.	Conditional	Low
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

NMBA Antagonism



Optimal NMB Management

Monitoring

- SGX without monitoring resulted in up to 9.4% of patients with residual weakness after extubation
- “We found that reversal with sugammadex failed to eliminate the occurrence of postoperative residual weakness”

Kotake Y, et al. Anesth Analg. 2013 Aug;117(2):345-51.

Your Practice

Introducing monitoring into practice

Society for Technology in Anesthesia

Section Editor: **Maxime Cannesson**

The Implementation of Quantitative Electromyographic Neuromuscular Monitoring in an Academic Anesthesia Department

Michael M. Todd, MD, Bradley J. Hindman, MD, and Brian J. King, BA

ANESTHESIOLOGY

Quantitative Neuromuscular Monitoring in Clinical Practice: A Professional Practice Change Initiative

Wade A. Weigel, M.D., Barbara L. Williams, Ph.D., Neil A. Hanson, M.D., C. Craig Blackmore, M.D., M.P.H., Randy L. Johnson, Cer.A.T., Gary M. Nissen, M.D., Andrew B. James, M.D., Wyndam M. Strodtbeck, M.D.

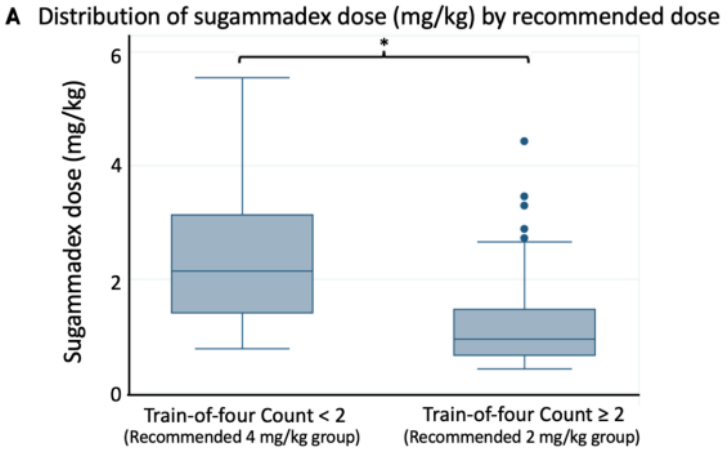
ANESTHESIOLOGY 2022; 136:901–15

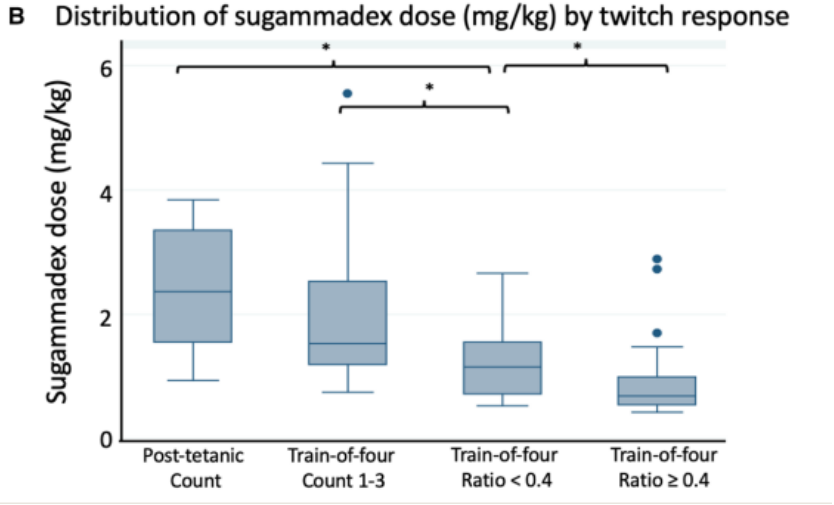
Todd MM, et al. Anesth Analg. 2014 Aug;119(2):323-331.
Weigel WA, et al. Anesthesiology. 2022 Jun 1;136(6):901-915

Path to success

- Local champions
- EMR Integration
- Demonstrate value
- Accountability
- Continued education
- Picking the right monitor(s)

Impact on Sugammadex Usage





- 87% required less than the manufacturer recommendations
- 13% required more

Bowdle TA, et al. Anesthesiology. 2023 Jul 1;139(1):6-15.

Take home points

- Monitoring + reversal = best practice
- Place the monitor pre-induction
- Normalize AMG, try to keep thumb free
- EMG for tucked arms
- PTC for deep blockade
- Muscle groups respond differently to NMB
- Changing the practice is work but monitoring can add value

Questions?

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