Neuromuscular Blockade: Summary of Recommendations

Objectives

PROVIDE OVERVIEW OF NEUROMUSCULAR BLOCKADE

REVIEW GUIDELINES FOR MONITORING NEUROMUSCULAR BLOCKADE (NMB)

DISCUSS MEDICATIONS USED FOR PARALYSIS AND REVERSAL

DEFINE QUALITATIVE VS QUANTITATIVE MONITORING

Neuromuscular Blocking Agents

Neuromuscular blocking agents are muscle relaxants that block transmission at the neuromuscular junction and cause paralysis of affected skeletal muscles.

Types of Neuromuscular Blocking Agents	
Depolarizing	**Non-Depolarizing**
➢Succinylcholine	➢Vecuronium ➢Rocuronium ➢Cisatracurinum

Neuromuscular Blockade Benefits/Risks

- Neuromuscular blocking drugs, both depolarizing and nondepolarizing are used to facilitate airway management, improve surgical conditions, and, in some cases, to ensure immobility during critical points in an operation.[1]

- The use of NMBs is associated with serious complications when their paralytic effects have not disappeared or been reversed at the end of surgery. Inadequate recovery from the effects of neuromuscular blocking drugs is associated with adverse outcomes.[1]

1. Thilen, Stephan R., Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, et al. 2023. "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." *Anesthesiology* 138 (1): 13–41. doi: https://doi.org/10.1097/ALN.0000000000004379

Risk: Residual Weakness

- Consequences of Residual Neuromuscular Blockade
  - Hypoxemia
  - Impaired pulmonary function
  - Postoperative Pneumonia
  - Respiratory Failure
  - Subjectively worse recovery

- Avoiding residual weakness can be accomplished by measuring the patent's train-of-four ratio and ensuring a ratio >/= to 0.9 prior to extubation.

- ASA 2023 Practice Guidelines recommend quantitative neuromuscular monitoring over qualitative assessment to avoid residual neuromuscular blockade.
  - Strength of recommendation: Strong
  - Strength of evidence: Moderate [1]

1. Thilen, Stephan R., Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, et al. 2023. "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." *Anesthesiology* 138 (1): 13–41. doi: https://doi.org/10.1097/ALN.0000000000004379

Train-of-Four Monitoring

Train of Four (TOF) is used to measure the depth of neuromuscular blockade using a peripheral nerve stimulator (PNS). The PNS delivers four equal pulses/stimuli to a nerve at 2 Hz. The train of four count is the counting of muscle twitches in response to each stimuli.

1. Thilen, Stephan R., Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, et al. 2023. "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." *Anesthesiology* 138 (1): 13–41. doi: https://doi.org/10.1097/ALN.0000000000004379

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What is Post-Tetanic Count (PTC)?

- When TOF Count is 0/4, PTC is measured to assess depth of blockade.

- PTC applies high frequency tetanic stimulation of 50-Hz for 5 seconds, followed by a 3 second pause and then a single twitch stimulation at 1 Hz.

- Quantitative monitors with PTC functionality result a number between 0 - 15.

- More twitches = closer to recovery of TOF Count: 1/4

- Conversion for Monitoring Sites:
  - TOF Count: 1/4 at orbicularis oculi (face) = TOF 0/4 with 5-10 PTC count at AP (hand)

- If TOF=0/4 but diaphragm is signaling recovery based on ventilator response: *Patient is at shallow end of deep blockade. Measure PTC count. Readminister rocuronium at PTC count between 5 and 10 to maintain deep level of blockade.*

ASA Guidelines

Recommends objective or quantitative monitoring whenever neuromuscular blocking agents are used.

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

Volume 138, Issue 1

January 2023
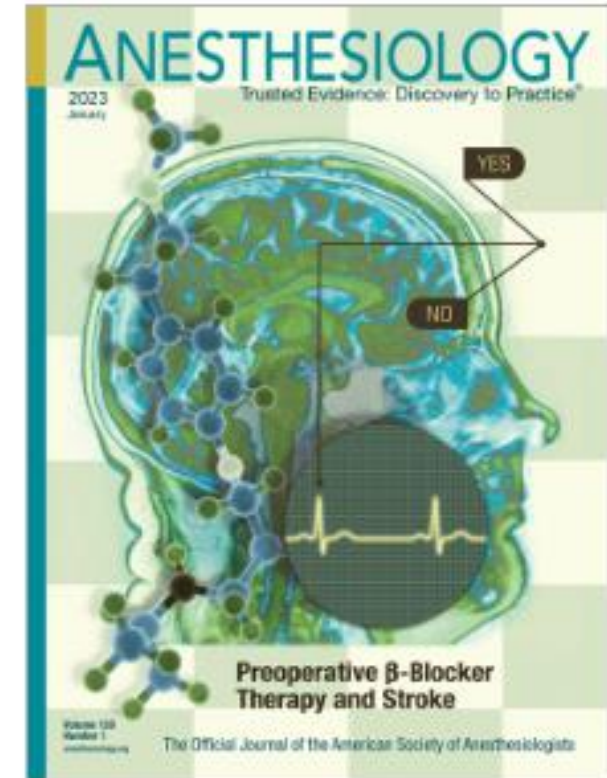
Stephan R. Thilen, Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, Lars I. Eriksson, Myron Yaster, Mark D. Grant, Madhulika Agarkar, Anne M. Marbella, Jaime F. Blanck, Karen B. Domino; 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. Anesthesiology 2023; 138:13–41 doi: https://doi.org/10.1097/ALN.0000000000004379

Monitoring Sites

Common Sites

- **Diaphragm:** Recovers from blockade first but cannot monitor.
- **Adductor pollicis (hand):** Recovers from blockade last. <mark>Recommended</mark>
- If hand not accessible, orbicularis oculi (facial) or posterior tibial (ankle) nerve can be used.
  *Strong evidence against using posterior tibial nerve in patients with peripheral neuropathy.

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

When is NMB Reversal needed?

Patients with adequate spontaneous recovery of train-of-four ratio ≥ 0.9 can be identified with quantitative monitoring. These patients do not require pharmacological antagonism. [1]

Defasciculating dose: Nondepolarizing agent given to reduce the duration and intensity of muscle twitches when succinylcholine is used. Recommended dose is 10% of paralyzing dose.

<u>Note</u>: If defasciculating dose was administered, TOF is recommended with reversal advised for ratios <0.9.

1. Stephan R. Thilen, Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, Lars I. Eriksson, Myron Yaster, Mark D. Grant, Madhulika Agarkar, Anne M. Marbella, Jaime F. Blanck, Karen B. Domino; 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. Anesthesiology 2023; 138:13–41 doi: https://doi.org/10.1097/ALN.0000000000004379

Assess Level of Blockade

If TOF Count <4/4, **sugammadex** is recommended to reverse deep and moderate blockade from rocuronium and vecuronium.

FDA- approved dosing recommendations for sugammadex:
- TOF ≥2/4: 2 mg/kg
- TOF <2/4: 4 mg/kg
- Emergency Reversal needed after single dose of rocuronium: 16 mg/kg

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

*Sugammadex does not reverse neuromuscular blockade induced by cisatracurium or succinylcholine.

Assess Level of Blockade

If TOF Count = 4/4 with ratio 0.4-0.9 (**minimal blockade**), **neostigmine** is an acceptable alternative for reversal.

- Neostigmine can reverse the effects of rocuronium, vecuronium, or cisatracurium.

- Neostigmine dose should not exceed 40 µg/kg.

- Doses higher than 50µg/kg associated with paradoxical effect.

- When neostigmine has reached peak effect, and the TOF count is 4/4 but ratio is <0.9:
  1. Allow for continued spontaneous recovery, if situation allows
  2. Administer sugammadex if rocuronium or vecuronium were used
  3. If a low dose of neostigmine was initially used, administer additional neostigmine (not to exceed a total of 50 µg/kg) [1]

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

1. Stephan R. Thilen, Wade A. Weigel, Michael M. Todd, Richard P. Dutton, Cynthia A. Lien, Stuart A. Grant, Joseph W. Szokol, Lars I. Eriksson, Myron Yaster, Mark D. Grant, Madhulika Agarkar, Anne M. Marbella, Jaime F. Blanck, Karen B. Domino; 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. Anesthesiology 2023; 138:13–41 doi: https://doi.org/10.1097/ALN.0000000000004379

Qualitative Monitoring

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Qualitative Monitoring (Subjective)

Qualitative monitoring can be assessed in the following ways:

1. Clinical assessment - Asking patient to respond to directions. <u>This method is not reliable for assessing recovery from neuromuscular blockade.</u>

2. Peripheral nerve stimulator: Train-of-four Count

   - Provider counts twitches.
   - Difficult to decipher difference in twitch strength between first and fourth twitch.
   - Sustained Tetany: Muscle twitches appear to have the same intensity between first and fourth twitch. It can seem that there is no fade however, **fade cannot be reliably detected until the TOF ratio is > 0.4**
   - **PNS are inadequate at low levels of blockade**

Qualitative Monitoring (Subjective)
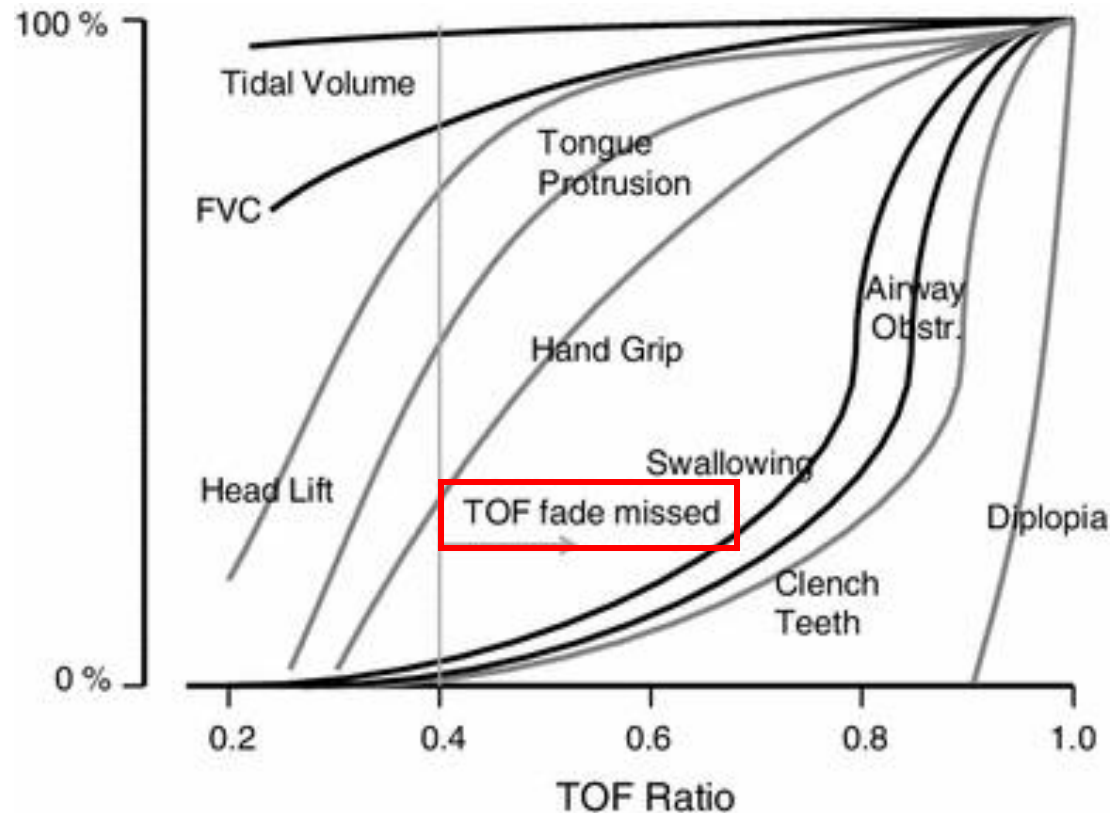
Clinical Assessment:
- Tidal volume
- Grip strength
- Ask patient to raise head

*Not reliable clinical indicators.

TOF Fade: In a partially paralyzed muscle, the response to the second burst using TOF is reduced.

Donati F. Residual paralysis: a real problem or did we invent a new disease? Can J Anaesth. 2013 Jul;60(7):714-29. doi: 10.1007/s12630-013-9932-8. Epub 2013 Apr 27. PMID: 23625545.

MPOG Variable Mapping:
Qualitative NMB Monitoring Concepts

MPOG Concept ID	MPOG Concept Name	Example Variables
3330	Train-of-four Qualitative (Subjective, Clinican Reported) Count	TOF Count: (0,1,2,3,4, ST)
3487	Subjective Clinical Neuromuscular Monitoring Assessment (head lift, hand grasp)	Patient can lift head, hand grasp strong/weak

Quantitative Monitoring

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Train-of-Four (TOF) Count

- TOF Count: Measures the magnitude of muscle twitch along a nerve (adductor pollicis used most common) displayed as a percentage. This is measured four times, spaced out over half a second each.

    - T1 = Twitch 1
    - T2 = Twitch 2
    - T3 = Twitch 3
    - T4 = Twitch 4

  - Prior to giving the non-depolarizing medication, we expect to see the ratio between T1 & T4 = 100% (equal twitch strength).

  - One minute after administering the medication, magnitude of muscle twitch decreases.

    For example:
    - T1 = 100%
    - T2 = 70%
    - T3 = 50%
    - T4 = 30%

    Ratio = 0.3

Train-of-Four Ratio Explained

- **TOF Ratio = T4/T1**

- Using our example, we would use the magnitude of the fourth twitch divided by magnitude of the first twitch.
  - T1 = 100%
  - T2 = 70%
  - T3 = 50%
  - T4 = 30%

  - **T4/T1** = 30%/100% = Ratio of 0.3
  - After another minute, rocuronium is administered and you assess your patient again. Here are the counts:
    - T1 = 75%, T2=50%, T3=30%, T4=15%.
    - Leaving us with a TOF Count: 4/4 with **Ratio** = 0.2 (15%/75%)
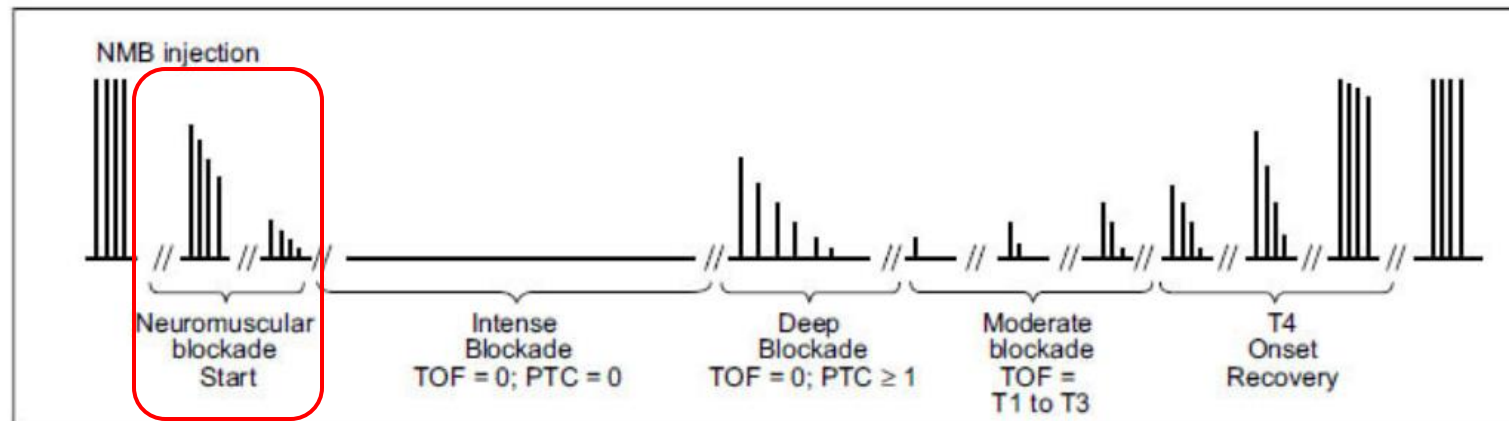
Quantitative Monitoring (Objective)
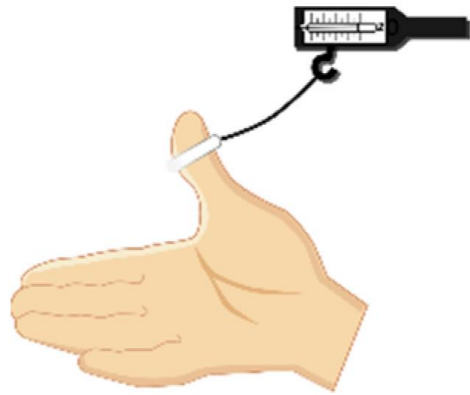
(a) Mechanomyography
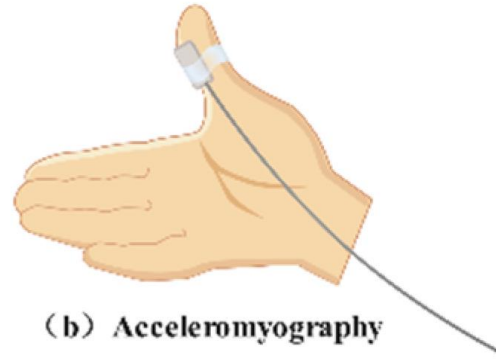
(b) Acceleromyography

(c) Electromyography
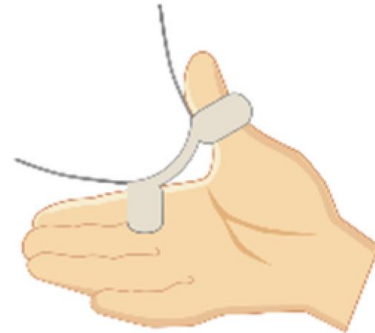
(d) Kinemyography

- Device applied to stimulate a peripheral nerve to measure the depth of neuromuscular blockade.
- Reports both a TOF count and ratio

Calibration and Normalization- Quantitative Monitoring

Calibration

- Adds a few extra steps in beginning of case
  - Can be omitted if delays are a patient safety concern
  - Median time to calibrate was 34 seconds [1]
 - Allows for accurate baseline measurement

Normalization

- Using baseline value, calculate the recovery percentage needed for each patient.
  - Baseline value % X 0.9
  - Can raise threshold of recovery to adjust to patient's baseline

Baseline values can be larger than 100%

1. Renew JR, Hex K, Johnson P, Lovett P, Pence R. Ease of Application of Various Neuromuscular Devices for Routine Monitoring. *Anesth Analg*. 2021;132(5):1421-1428. doi:10.1213/ANE.0000000000005213

Mechanomyography

- Measures isometric contractile force after neurostimulation.
- Detects changes in active skeletal muscle.
- <mark>Regulated to research use</mark>
- Historic gold standard: All new monitors are validated against mechanomyography prior to release.
- Not common for daily practice.
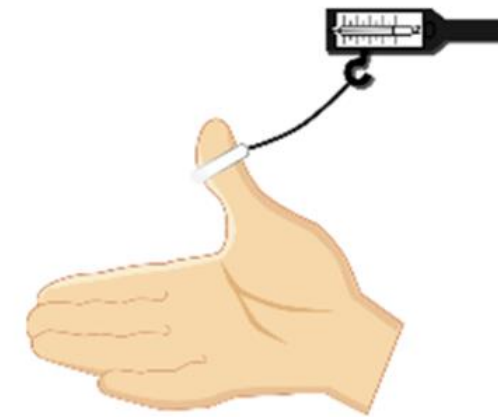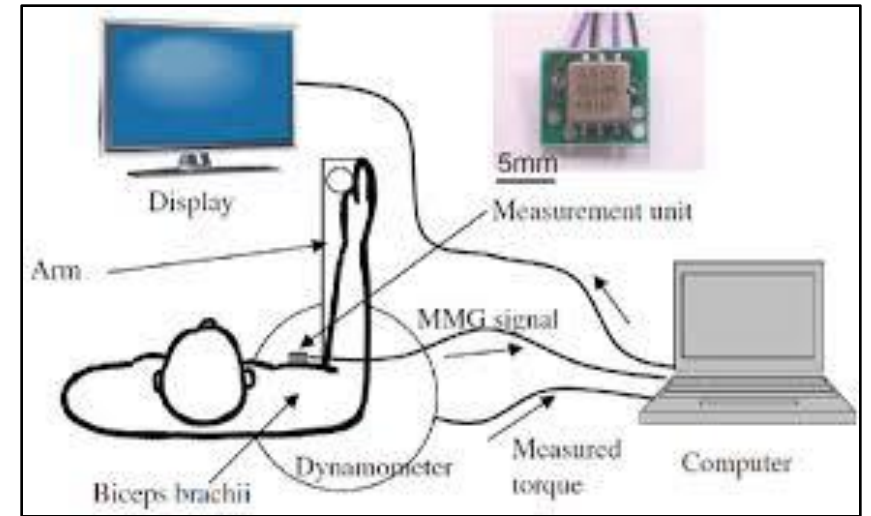
(a) Mechanomyography

Acceleromyography (AMG)

- Most frequently studied

- Transducer fixed to thumb: 3D transducers can measure acceleration of thumb movements following neurostimulation.

- Can use EKG leads to reduce cost

- Bluetooth connectivity

- Reverse Fade Phenomenon: Baseline measurements can exceed 100% in sleeping patient prior to paralytic.

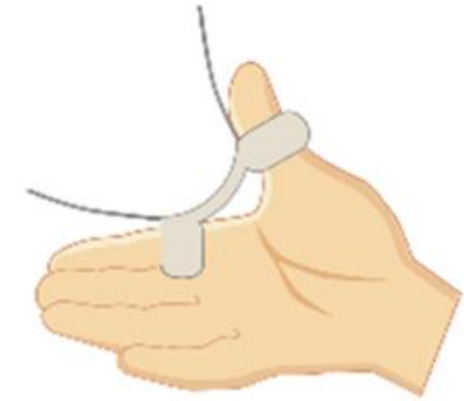**Important to place the monitors on pre-induction to get baseline value for normalization.**
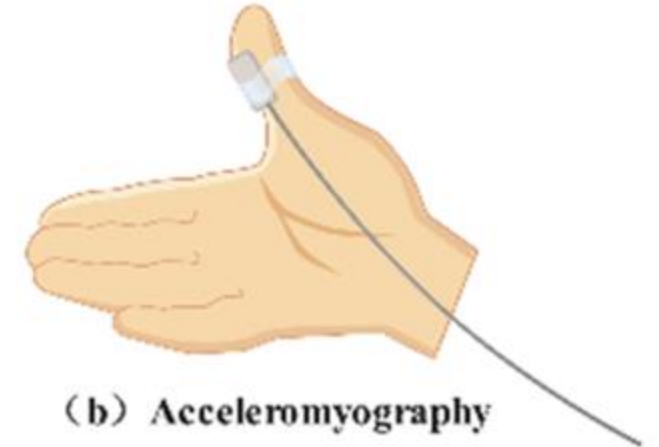
(b) Acceleromyography

Kinemyography

- Similar to acceleromyography
- Degree of bend from piezoelectric sensor is objective measurement
- **Not associated with reverse fade phenomenon**
- Limited research available.

(d) Kinemyography

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Electromyography (EMG)

- Measures electricity rather than motion - can be used when AMG fails or arms are tucked.

- Used for Neuro/Spine cases

- Consistent response

- Susceptible to interference from electrical equipment (cautery)

- Lower temperatures (< 34C) can amplify measure response

- Higher cost due to single use electrodes.

- **Portable**:   **Operating Rooms:**

(c) Electromyography
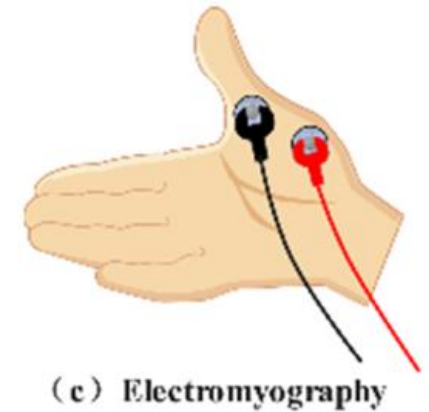
MPOG Variable Mapping: Quantitative NMB Monitoring Concepts

MPOG Concept ID	MPOG Concept Name	Example Variables
3033	Train-of-four Quantitative (Objective, From Device) Count	TOF Count (0, 1, 2, 3, 4)
3485	Train-of-four Quantitative (Objective) Ratio	TOF Ratio: decimals, % or values >1/4
3486	Train-of-four Quantitative (Objective) Count and Ratio combined	TOF Count + ratio: 4/4 55%
3488	Train-of-four Post Tetanic Count (PTC)	Count, 5/20 (fraction)

MPOG QI Measures: Neuromuscular Blockade

NMB-01- Train of Four Taken

NMB-02- Reversal Administered

NMB-03 Peds- NMB Dosing, Pediatrics

NMB-04 – Variation in Sugammadex Administration

NMB-05- Quantitative NMB Monitoring

Summary of Recommendations

- Quantitative NMB monitoring is recommended for all patients receiving neuromuscular blockade.

- Muscles respond differently to NMB – adductor pollicis is recommended site for TOF monitoring.

- Fade is not reliably detected with the naked eye until train-of-four ratio is >0.4.

- Calibration of the NMB monitor allows the provider to obtain baseline data before induction

- Acceleromyography is most commonly used form of quantitative monitoring.

- Use EMG when arms need to be tucked.

- Reversal with sugammadex is recommended for deep & moderate levels of neuromuscular blockade from rocuronium or vecuronium.

- Reversal with neostigmine is acceptable for patients with minimal blockade from vecuronium or rocuronium or for patients receiving cisatracurium.

Please contact support@mpog.zendesk.com with any questions.

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