Quantitative Neuromuscular Blockade Monitoring

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Objectives

- Review train-of-four and train-of-four ratio

- Define residual neuromuscular blockade and discuss clinical implications

- Define and discuss subjective neuromuscular blockade monitoring

- Define and discuss objective neuromuscular blockade monitoring

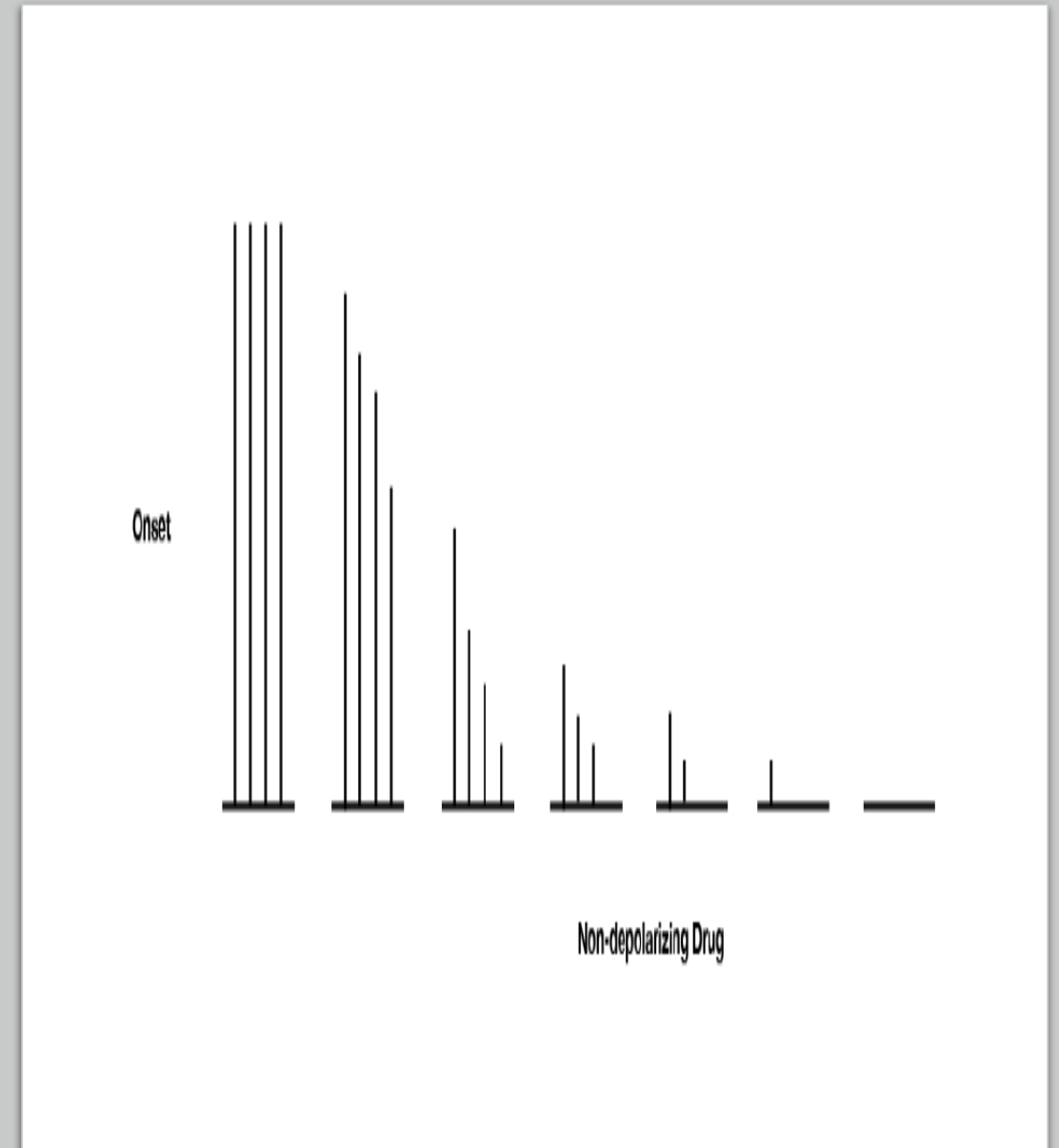- Review of current research and recommendations

Train-of-Four

Best Method

- Ulnar nerve by adductor pollicis muscle
  - Proper placement

Golinski et al. (2018)

Train-of-Four

- 4 responses = 70% block (TOFR > 0.9)
- 4 responses = 70-75% block (TOFR < 0.9)
- 3 responses = 75-80% block
- 2 responses = 80-85% block
- 1 response = 90-95% block
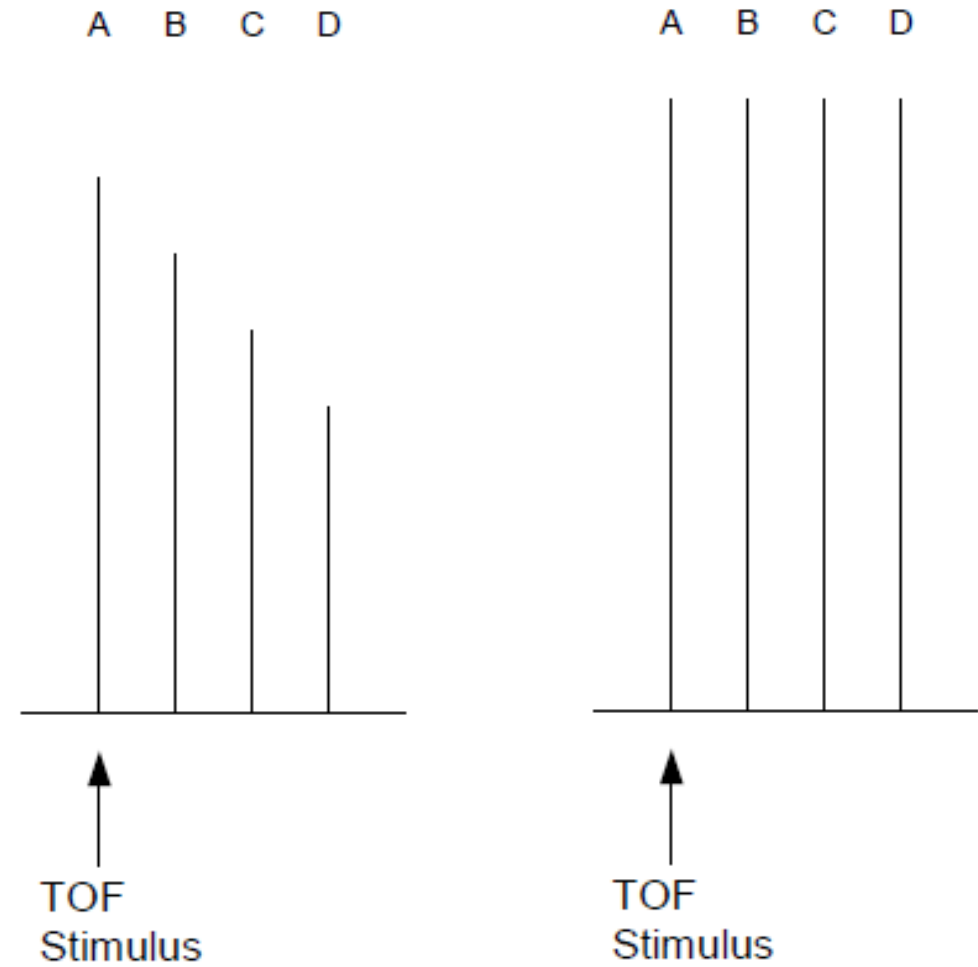- 0 responses = 100% block

Onset

Non-depolarizing Drug

Percent Neuromuscular Blockade

Nagelhout & Elisha (2017)

Train-of-Four Ratio

Comparison of strength of 4th twitch to 1st

$$TOFR = T_4/T_1$$

Nagelhout & Elisha (2017)

What is SAFE for neuromuscular blockade recovery?

1970–1990

TOFR ≥ 0.7

Current

TOFR ≥ 0.9

Brull & Kopman (2017)

TOFR < 0.9

- Diplopia
- Difficulty speaking
- Misdirected swallowing
- Aspiration
- Symptoms of muscle weakness
- Impaired pharyngeal musculature
- Compromised airway patency
- Hypoventilation, hypoxemia
- Decreased hypoxic ventilatory response
- Respiratory distress

Dutu et al. (2018)

Residual Neuromuscular Blockade (RNMB)

- Skeletal and upper airway muscular weakness

- Partial or complete airway obstruction

- Concurrent hypoxemia

- Respiratory failure requiring reintubation

Dutu et al. (2018)

Survey says…

- 77% believed RNMB to be a 'significant public health problem'

- 41% admitted to not routinely using neuromuscular blockade

- 34% indicated they generally omit reversal

Naguib et al. (2018)

Incidence	Issue
12%	Incidence of TOFR < 0.7 postop
41%	Incidence of TOFR < 0.9 postop
40%	Incidence of RNMB immediate postop
112,000	# patients annually in the US that are at risk of critical respiratory events associated with undetected RNMB
0.05-0.19%	Reported incidence of reintubation in PACU directly attributed to inadequate recovery from neuromuscular function

Murphy and Brull (2010)
Naguib et al. (2018)

This latter group was observed for evidence of recurring paralysis.

We found no evidence of recurarization in our study patients. We do not deny that recurarization exists, but feel that it is likely to occur only when gallamine is given to patients with renal disease. Many cases of recurarization reported in the literature seem, in retrospect, to be more likely problems of overdosage with neuromuscular blocking drugs or inadequate drug antagonism. We believe the anesthesiologist can best avoid these problems of overdose or inadequate antagonism by using a nerve stimulator as an aid to management of relaxation in the anesthetized patient.

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Neuromuscular Blockade Monitoring
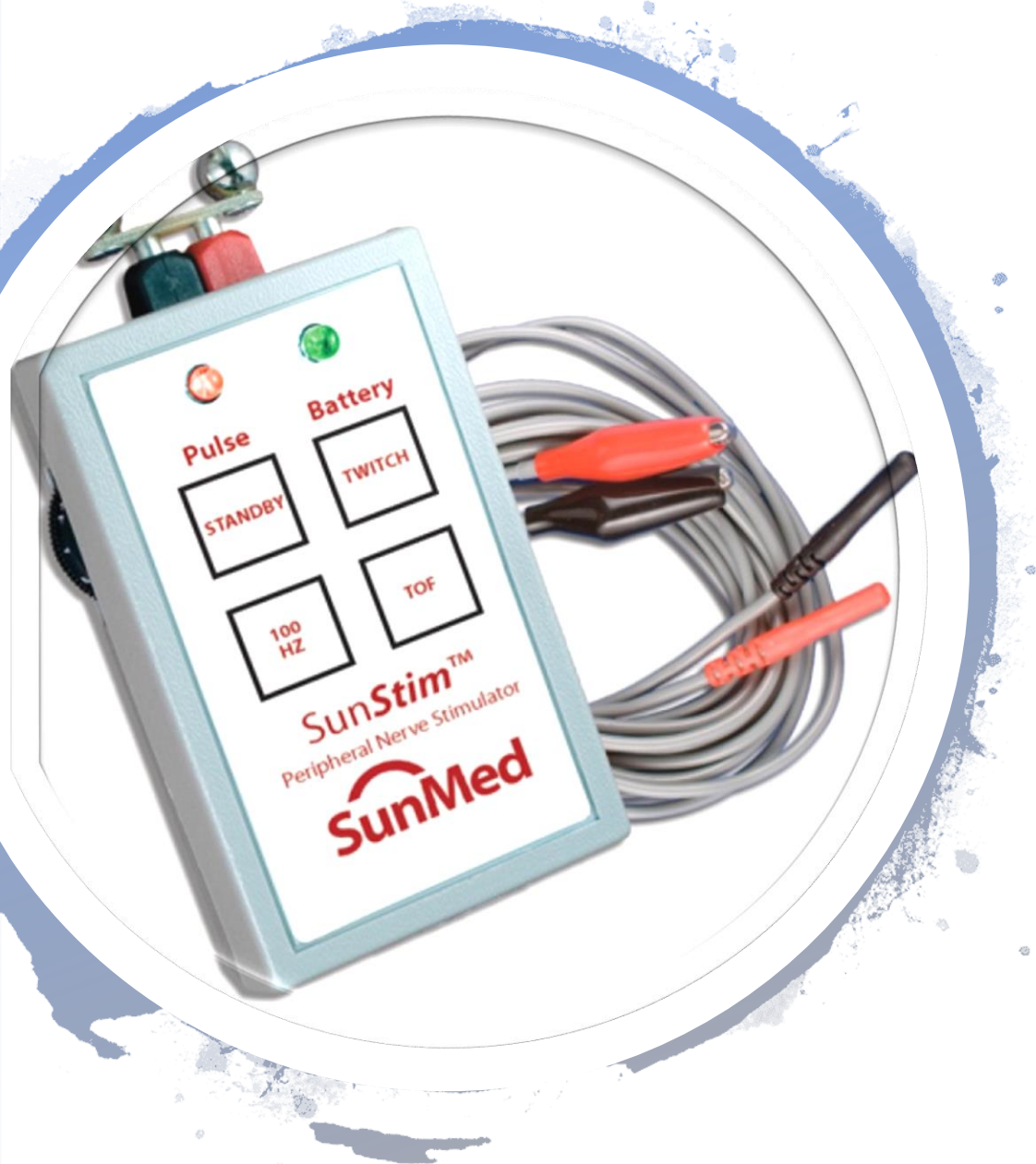
Subjective Measures

- Observation or palpation of the elicited muscle twitches

- Peripheral Nerve Stimulator
  - Sends electrical impulses to a peripheral nerve to stimulate the corresponding muscle to contract
  - Modes
    - Single-twitch
    - TOF
    - Tetanus
    - Double-burst

McGrath & Hunter (2006)

Traditional Methods

5-second head lift

Grip strength

Vital capacity

Inspiratory force

Tidal volume

Visual or tactile observation of fade by peripheral nerve stimulator

Nagelhout & Elisha (2017)

How do our traditional methods measure up?

Test	Approximate % of Receptors Occupied when Response Returns to Normal
5-second Head Lift Hand Grip Sustained Bite Inspiratory Force -40 cmH$_2$O	50
Vital Capacity 20 mL/kg	70
Tidal Volume 5mL/kg	80

Nagelhout & Elisha (2017)

Current Practice Guidelines

AANA

Standards for Practice state "…when neuromuscular blockade agents are administered, monitor neuromuscular response to assess depth and degree of recovery."

ASA

No current requirement for neuromuscular monitoring.

Updated report states "…assessment of neuromuscular function primarily includes physical examination and **on occasion, may include NMBA monitoring**."

Bhananker et al. (2015)

TOFR

Variability

- Monitor functionality
- Anatomical placement
- Differences in interpretation among clinicians

Research

- 97% agreement when TOF was 0 or 4
- **36%** agreement when TOF was 1, 2, or 3
- Clinicians assessed a higher TOF than was present **96%** of the time

Bhananker et al. (2015)

How good are we?

- Inexperienced
  - Able to feel fade only when TOFR < 0.30
- Extensive experience
  - Unable to detect fade 80% of the time when TOFR 0.51–0.70
- Majority
  - Unable to detect fade when TOFR > 0.40
- Most clinicians are unaware of the limitations of subjective evaluation of TOF fade

Brull & Murphy (2010)

Confidence vs Accuracy

83.5%

57.1%

P < 0.001

Naguib et al. (2018)
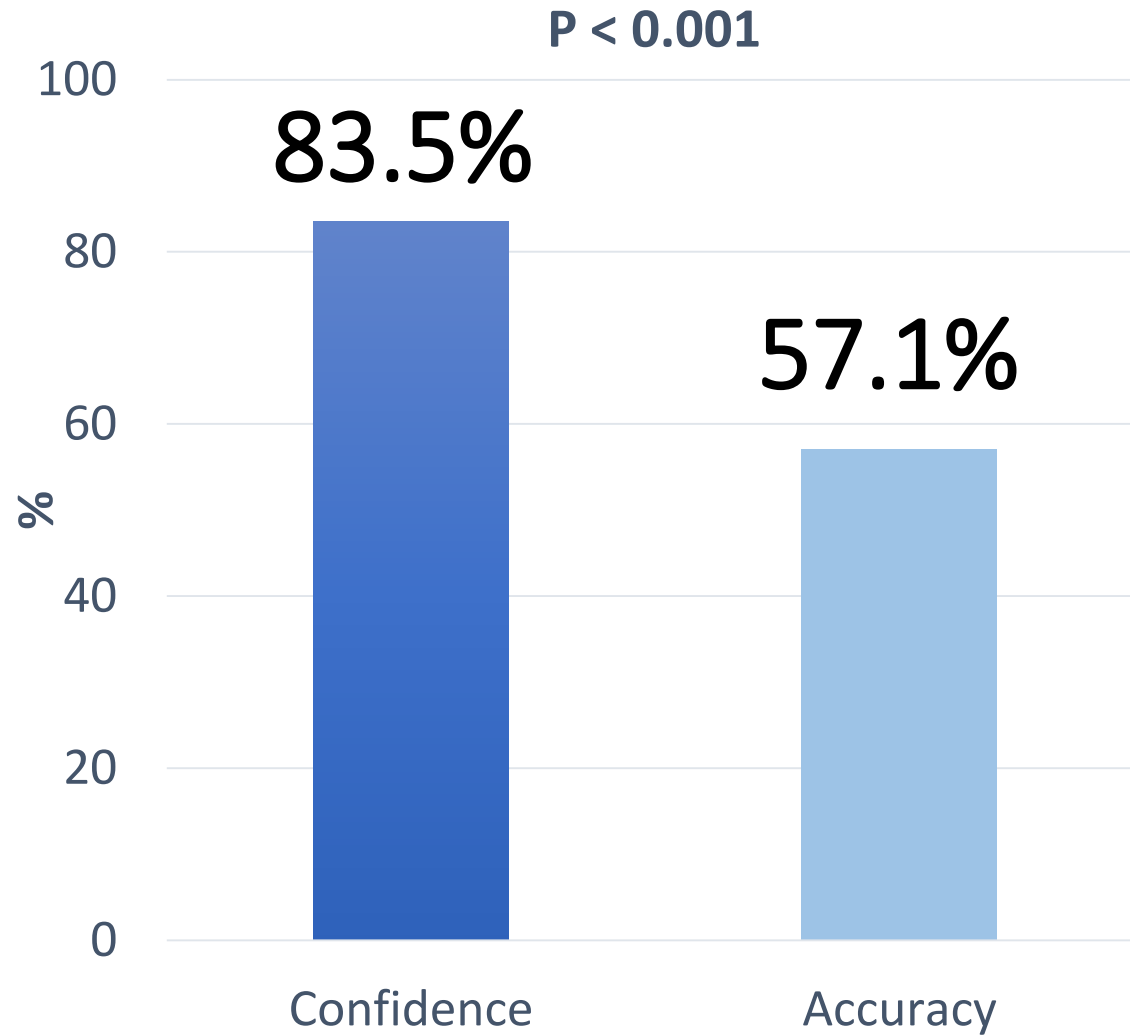
Quantitative vs Qualitative

- Structured data
- Statistical analysis
- Objective conclusions
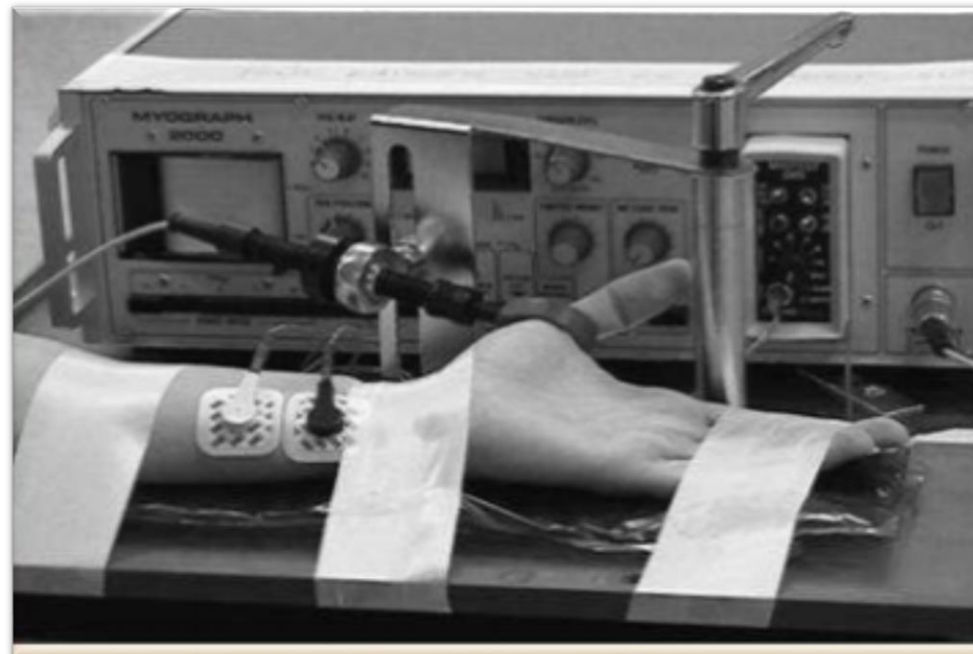- Surveys, Experiments

- Unstructured data
- Summary
- Subjective conclusions
- Interviews, focus groups, observations

Types of Quantitative Monitors

Mechanomyography (MMG)

- 'Gold Standard'
- Cumbersome and time-consuming
- Only seen in research

Dutu et al. (2018)

MMG

- Thumb placed on a force transducer under mild tension (200-300 g preload)

- Produces an isometric contraction

- Force of contraction is converted to an electrical signal

- Amplitude of the signal is recorded on an interfaced pressure monitor

- Amplitude is proportional to the strength of muscle contraction

- Measurement of TOFR will yield precise and reproducible results

Brull & Kopman (2017)

Electromyography (EMG)

- Measurement of the muscle action potential following nerve stimulation

- Advantages:
  - Best indicator of pure neuromuscular function
  - Free muscle movement is not required

- Disadvantages:
  - Influenced by surrounding electronics
  - 5 electrode setup
  - Expensive

- Stand-alone, portable device is currently under development

McGrath & Hunter (2006)

Kinemyography (KMG)

- Measure degree of bending of a piezoelectric sensor

- Mechanosensor placed along the space between thumb and index fingers

- Quantifies degree of bending as the thumb and index fingers appose in response to ulnar nerve stimulation

Brull & Kopman (2017)

Acceleromyography (AMG)

- Introduced in 1988
- Similar to KMG
- Newer versions available
- Most widely used in clinical setting
- Compact, designed for intraop use
- Costs range $800-2,400

McGrath & Hunter (2006)
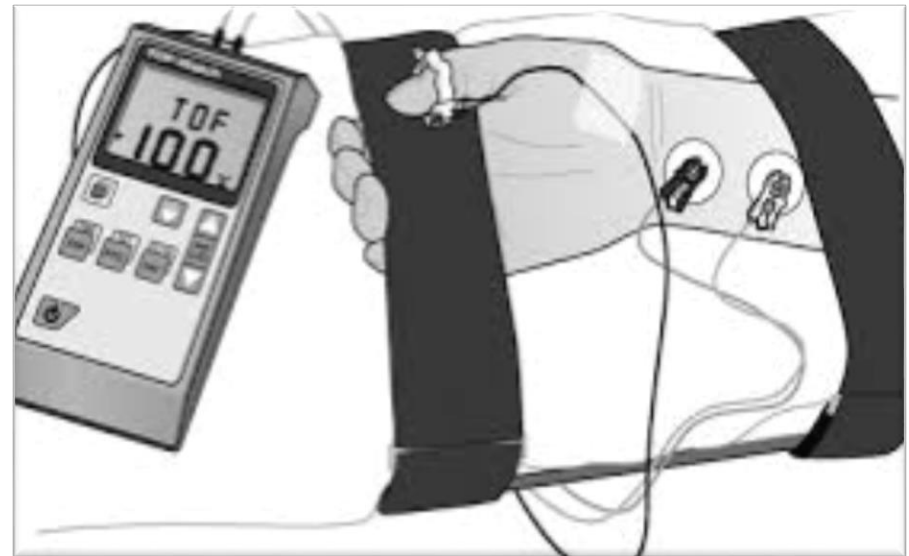
AMG

- Transducer is fixed to the muscle of interest and senses the movement, generating an electrical signal which is converted into numeric output representing TOFR

- Measurement of acceleration of the stimulated muscle with a piezoelectric sensor

- Piezoelectric – the ability to generate an electric charge in response to applied mechanical stress

- Force = mass x acceleration

- Only measures TOF or post-tetanic count (PTC)

Brull & Kopman (2017)

TOF-Watch™

- Acceleration of the muscle is measured in only one direction – perpendicular to the face of the monitor

Drawbacks
- The thumb must be free of manipulation as this could lead to artifact and reading errors
  - Solution – preload device
  - If the thumb is stabilized and placed under a fixed amount of tension (preload), then evoked responses can be measured as a change in tension develops
- Overestimation of TOFR
  - Solution – normalize baseline values
  - Baseline TOFR = 1.25; Adequate recovery (0.9) = 1.25 x 0.9 = 1.125

Bhananker et al. (2015)

Staircase Effect

- Repeated indirect stimulation may enhance the evoked mechanical response of muscle

- After spontaneous recovery of the TOFR to ≥ 0.80, T_1 frequently returned to values > 150% of control

- 2nd (and often 3rd and 4th) twitch may exceed the 1st

Kopman et al. (2015)
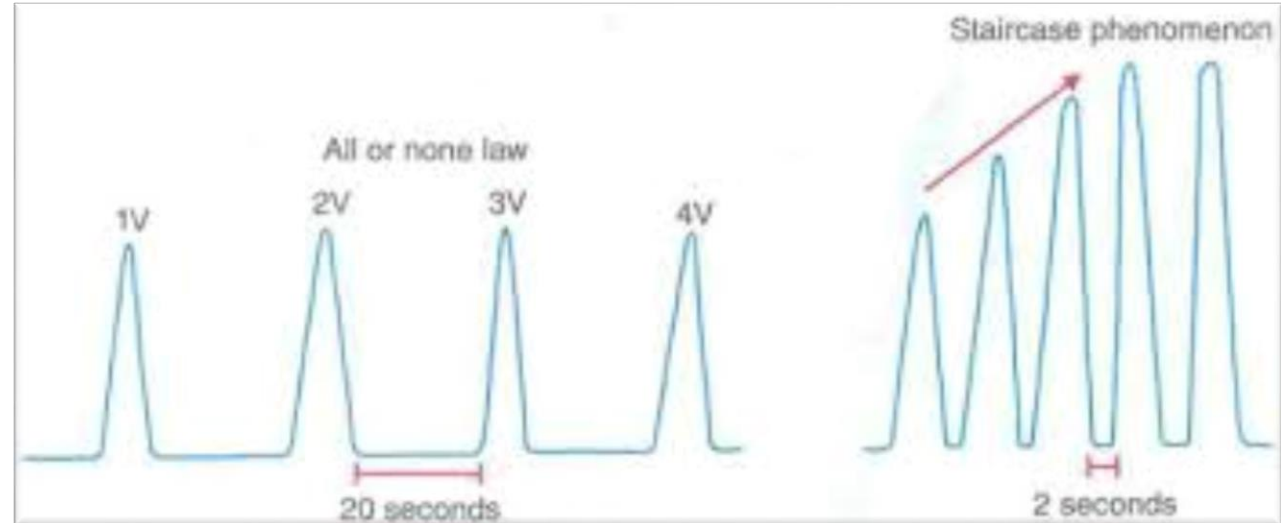
TOF-Watch SX

- Fixes issue with overestimated TOFR

- When staircase occurs, monitor displays the T_4/T_2 rather than T_4/T_1

- If this ratio > 1.0, the monitor will limit the display to 100%

Murphy & Brull (2015)

TOFscan

- 3-D piezoelectric sensor attaches to thumb via a hand adapter
- Measures acceleration in multiple planes
- 3 joints, frictional forces, and deformation of tissues
- Transducer encased in a thumb splint
- Optimal positioning, applies a preload, minimizes risk of TOFR exceeding 1.0

Murphy & Brull (2015)

Calibration

TOF-Watch SX

- Adjusts stimulation current to determine supramaximal stimulation
  - Electrical stimulus 15–20% above that necessary to produce contraction of all the muscle fibers supplied by the nerve
  - Increases the probability that the TOF responses will be within the measurement window
  - Reduces risk of significant background noise

TOFscan

- Fixed, noncalibrated current intensity with a default output of 50 mA

Good agreement between TOF-Watch SX
with calibration and preload application
and the uncalibrated TOFscan

Colgrave et al. (2016)

Compatibility

The IntelliVue NMT module estimates the degree of neuromuscular transmission and integrates it with other parameters on Philips IntelliVue MP40-MP90, MX600-MX800 patient monitors, rev. J.0 and above.

Your objective measure of muscle relaxation

Philips IntelliVue NMT Module

Consensus Recommendations

- Whenever a neuromuscular blocker is administered, neuromuscular function must be monitored by observing the evoked muscular response to peripheral nerve stimulation.

- **Objective monitoring** (documentation of TOFR ≥ 0.90) is the **only method** of assuring that satisfactory recovery from neuromuscular function has taken place.

Naguib et al. (2018)

Consensus Recommendations

- **Subjective or clinical tests** of neuromuscular blockade are **not predictive** of adequate recovery and are **not sensitive** to the presence of residual neuromuscular weakness.

- **Subjective** evaluation or **clinical tests should be abandoned** in favor of objective monitoring.

- Professional organizations should develop practice standards for how to best monitor and manage perioperative administration of NMB drugs.

Naguib et al. (2018)

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