Muscular relaxation & neuromuscular monitoring in the Perioperative environment
• Muscular relaxation and neuromuscular monitoring: facts & figures
• Anaesthesia societies recommendations and guidelines
• Residual neuromuscular blockade: a patient safety hazard
• Remarkable clinical scenarios
• Benefits of applying systematic neuromuscular monitoring
• NMT stimulation modes and application
• NMT monitoring technology: state of art
• Conclusion and take away
Muscular relaxation and neuromuscular monitoring: Facts & Figures

Neuromuscular block often persists in PACU, even with the administration of reversal. The frequency ranges between 4% and 50% (Buttery A. et al., 2010; Plaud, B et al., 2010).

45% of patients had a TOF%<90 on arrival in the PACU after only a single intubating dose of NMBA (Debaene et al. Anesthesiology 2003).

In those patients for whom only ‘clinical criteria’ (e.g. head lift, leg lift, hand grip) were considered before tracheal extubation, more than 40% had a TOF%<90 (Cammu Anesth. Analg., 102, 426-429, 2006).

NMBA use was associated with a 40% increase in relative risk of reintubation, which itself increased the risk of hospital mortality 90-fold (Grosse BMJ., 345, e6329, 2012).


PACU: post anesthesia care unit
NMBA: neuromuscular block agent
TOF: train of four

PATIENTS %

<table>
<thead>
<tr>
<th>TOF% &lt; 70</th>
<th>TOF% &gt; 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>37%</td>
<td>10%</td>
</tr>
</tbody>
</table>

>2 hs between administration of muscle relaxants and arrival in PACU (n=238)
A study shows that between 1995 and 2004, a significant decrease in PORC in PACU was noted with an increased use of NMT monitoring and education (Baillard BJA Br. J. Anaesth., 95, 622-626, 2005).

Muscular relaxation and neuromuscular monitoring: Facts & Figures

Spain

763 patients from 26 hospitals, 26.7% of patients showed residual paralysis in PACU (Errando Minerva Anes 2016)

France

A study shows that between 1995 and 2004, a significant decrease in PORC in PACU was noted with an increased use of NMT monitoring and education (Baillard BJA Br. J. Anaesth., 95, 622-626, 2005).

Denmark, Germany, UK

Surveys have suggested that respectively only 43%, 28%, 10% of clinicians routinely use neuromuscular monitors (Naguib A&A 2010).

Neuromuscular transmission is insufficiently monitored in daily clinical practice

UK

In a study of 12 large anaesthesia departments, TOF monitors were only routinely used in 9% of cases; in 62% of cases, the monitors were never used (Sweeney Anaesthesia, 62, 806-809, 2007).

Europe

Only one third of the survey sample, considered necessary to monitor neuromuscular block with objective NMT monitoring. Only 45% of anaesthetists in Europe base their decurarization decision on TOF values (Naguib et al. 2007).

PACU: post anesthesia care unit
PORC: Post operative residual curarization
NMT: Neuromuscular transmission
TOF: train of four
Anaesthesia societies recommendations

Missing Guidelines

**AAGBI**

2015 Recommendations for standards of monitoring during anaesthesia and recovery mandates that “a peripheral nerve stimulator must be used whenever neuromuscular blocking drugs are given. It should be applied and used from induction until recovery from blockade and return of consciousness”

**APSF (ASA)**

Residual neuromuscular blockade in the postoperative period is a patient safety hazard that could be addressed completely by applying quantitative (objective TOF) monitoring along with traditional subjective observations to eliminate the problem

Current, there is a gap in terms of guidelines and recommendations of scientific societies on NMTM and PORC. In daily practice this coincides with a variety of management strategies for neuromuscular blockade

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2) An Updated Report by the American Society of Anesthesiologists Task Force on Postanesthetic Care - Anesthesiology, V 118 • No 2 - 2013
3) Post-Operative Residual Curarization (PORC): A Big Issue for Patients’ Safety Innocenti, Melotti
Residual neuromuscular blockade: a patient safety hazard


2) Debaene et al. Anesthesiology 2003

Worldwide

- 250M Ane procedures /year
- 50% in GA
- 51,75 M patients have PORC

100 Patients / min PORC

PORC Implications

- Need for tracheal intubation
- Impaired oxygenation and ventilation
- Reduced pulmonary function
- Risk of aspiration and pneumonia
- Discomfort for patients and operators
- Increased length of stay

1) GA: general anaesthesia
   PORC: Post operative residual curarization

Can patient surveillance be considered adequate in the Post Anaesthesia Care Unit?


2) Debaene et al. Anesthesiology 2003
Remarkable clinical scenarios

Laparoscopy: when deep NMB is required

Deep NMB can improve surgical conditions during laparoscopic surgery:

- Helps improving laparoscopic workspace
- Allows to work at lower insufflation pressure
- Avoids unwanted abdominal or diaphragmatic movements

- How to measure intense/deep/moderate block?
- How to optimize continuous NMBA infusion?
- When do you inject antagonist? In which dose?
- When do you extubate safely?


NMB: neuromuscular block
NMBA: neuromuscular blocking agents
TOF: train of four
Remarkable clinical scenarios

Obese: how to dose and how to measure drugs effect?

Effect (onset and duration) of Rocuronium in obese

Onset Time, Duration 25%, Spontaneous Recovery Index, Intubation Dose of Rocuronium

<table>
<thead>
<tr>
<th>Variable</th>
<th>Onset (s)</th>
<th>Duration 25% (min)</th>
<th>Recovery Index (min)</th>
<th>Dose (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Body Weight</td>
<td>77.0 [37-92]</td>
<td>55.5 [43.6-60.1]</td>
<td>16.6 [11.0-24.0]</td>
<td>67 [59-82]</td>
</tr>
</tbody>
</table>

\( P \) value

0.201 0.003 0.102 0.03

Adapted from Leykin Y et al. Anesthesia & Analgesia 2004;99:1086-9
Ingrande  BJA 2010 V105 i16-i23

Neostigmine: unpredictable timing on obese to full reversal

Time to recover from T1 to T4/T1 ratio of 0.5 0.7 and 0.9 with neostigmine dosed on Total Body Weight

<table>
<thead>
<tr>
<th>Time (seconds) from TOF 1.2 to 90% Sugammadex given in 2 mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBW</td>
</tr>
<tr>
<td>90s</td>
</tr>
</tbody>
</table>


Why do we need TOF > 90% before extubation?

➢ To reduce the risk of obstructive breathing
➢ Pharynx Dysfunction Increases the aspiration risk

### Guiding reversal with Neuromuscular Transmission Monitoring¹

<table>
<thead>
<tr>
<th>Block level</th>
<th>NMT monitoring (Adductor pollicis)</th>
<th>Reversal agent</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full recovery</td>
<td>TOF ratio &gt; 0.9 (≥ 1.0 with AMG?)</td>
<td></td>
<td>There is no monitoring able to confirm full recovery</td>
</tr>
<tr>
<td>Safe extubation</td>
<td>TOF ratio 0.5 - 0.9</td>
<td></td>
<td>Not needed</td>
</tr>
<tr>
<td>Recovery in process</td>
<td>TOF ratio 0.5 - 0.9</td>
<td>Neostigmine low dose</td>
<td>Pay attention to the delay and variability of neostigmine reversal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.02 mg/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neostigmine standard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>dose 0.05 mg/kg</td>
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<tr>
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<td>Neostigmine low dose</td>
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<td></td>
<td>0.02 mg/kg</td>
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<td>Neostigmine standard</td>
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<td>dose 0.05 mg/kg</td>
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<td></td>
<td>0.02 mg/kg</td>
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<td>dose 0.05 mg/kg</td>
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<td>dose 0.05 mg/kg</td>
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<td></td>
<td></td>
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<tr>
<td>Moderate NMB</td>
<td>TOF count 3-4</td>
<td>Neostigmine standard</td>
<td>Reversal threshold for neostigmine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dose 0.05 mg/kg</td>
<td>Maximal dose 0.07 mg/kg, ceiling effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep NMB</td>
<td>PTC 1-5-20</td>
<td>Sugammadex 4 mg/kg</td>
<td>Deep NMB (PTC 1-5) is useful to improve oro-tracheal intubation and surgical conditions</td>
</tr>
<tr>
<td>Intense NMB</td>
<td>PTC 0</td>
<td>Sugammadex 16 mg/kg</td>
<td>Rescue reversal if cannot intubate/ventilate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>There is no monitoring able to investigate intense NMB, which is of little interest in clinical practice</td>
</tr>
</tbody>
</table>

The use of a “one size fits all” dose of Sugammadex has been identified and requires further staff education²

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¹A review of the interest of sugammadex for deep neuromuscular blockade management in Belgium – Mulier Acta Anaesth. Belg., 2013, 64, 49-60

²Neuromuscular Monitoring, Muscle Relaxant Use, and Reversal at a Tertiary Teaching Hospital 2.5 Years after Introduction of Sugammadex: Changes in Opinions and Clinical Practice Thomas Ledowski, Jing Shen Ong, and Tom Flett
Why applying systematic neuromuscular monitoring?

To manage critical patients (diabetic, obese etc.)
To manage continuous infusion of muscle relaxants and avoid ‘unwanted’ accumulation
To establish the appropriate reversal dosage (depending on degree of block)
To establish the right time for safe extubation
For medical processes standardization
To analyse block onset time, duration of muscle relaxant and dose repetition
To analyse block level
To reduce risks of PORC
To manage continuous infusion of muscle relaxants and avoid ‘unwanted’ accumulation
To manage critical patients (diabetic, obese etc.)

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TOF: train of four
NMB: Neuromuscular block
PORC: Post operative residual curarization

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Intraoperative NMB agents monitoring and/or antagonists
PORC in recovery room (TOF ratio < 0.9)

% Patients

1995 N=435
2000 n=130
2002 n=101
2004 n=218

Adapted from Baillard et al. BJA 2005

Kopman et al. 2010
Mulier Acta Anaesth. Belg., 2013, 64, 49-60
Anesth&Analg August 2013 • Volume 117 • Number 2
NMT stimulation modes and applications

**Single Twitch**
- **Stimulus:** 0.2 ms, 0.1 Hz
- **Responses:** 10 s

**Train of Four**
- **Stimulus:** 0.2 ms, 500 ms (2 Hz)
- **Responses:** T1, T2, T3, T4

**Post Tetanic Count**
- **Stimulus:** Tetanic 5 s, 3 s, 20 single stimuli, 1 Hz
- **Responses:** Contraction

**Double Burst Stimulation**
- **Stimulus:** 0.2 ms, 20 ms, 750 ms
- **Responses:** Fade

Different types of peripheral nerves stimulation modes

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Duration</th>
<th>Interval</th>
<th>Repetition</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single twitch</td>
<td>0.1 Hz</td>
<td>0.2 ms</td>
<td>1-10 s</td>
<td>1-10 s</td>
<td>Induction</td>
</tr>
<tr>
<td>Tetanus</td>
<td>50 Hz</td>
<td>5 s</td>
<td></td>
<td>&gt;6 min</td>
<td>Induction, Maintenance, Intubation, Awakening</td>
</tr>
<tr>
<td>TOF</td>
<td>2 Hz</td>
<td>2 s</td>
<td>10 s</td>
<td>10 s</td>
<td>Deep block</td>
</tr>
<tr>
<td>PTC</td>
<td>50 Hz</td>
<td>2 s</td>
<td>10 s</td>
<td>&gt;6 min</td>
<td>Residual Curarization</td>
</tr>
<tr>
<td>DBS</td>
<td>50 Hz</td>
<td>40 ms</td>
<td>750 ms</td>
<td>&gt;6 min</td>
<td></td>
</tr>
</tbody>
</table>

To observe onset time at induction

No calibration most used but only for light block

When TOF is 0 it allows to monitor the level of deep block and recovery from block: PTC 10 light block; PTC 2 deep block

Adapted from: Post-Operative Residual Curarization (PORC): A Big Issue for Patients’ Safety A. Castagnoli, Innocenti et al. Anesthesiology and Intensive Care, S. Orsola-Malpighi Hospital, University of Bologna
NMT monitoring technology: state of art

Accelerography (ACG)? Kinemyography (KMG)? Electromyography (EMG)? Mechanomyography (MMG)?

Measure acceleration of muscles  
Measure force of muscle contraction  
individual muscle fibre potentials  
for research purpose only

TOF ratio of 0.90 measured with KMG will be approximately equivalent to a TOF ratio of 0.80 measured with EMG at the adductor pollicis muscle, but it may indeed be as low as 0.65 or as high as 1.00. Therefore, TOF ratios measured by KMG and EMG cannot be used interchangeably.

Comparison of electromyography and kinemyography during recovery from non-depolarising neuromuscular blockade Steward AIC 2014 May;42(3):378-84.

Acceleromyography-derived twitch heights for individual patients are not necessarily interchangeable with information obtained using electromyography.


EMG technology is more accurate and robust than AMG

Clinical validation of EMG and AMG as sensor for muscle relaxation Haenzi et al. EJA 2007 24(10):882-8
NMT monitoring technology: state of art

ACG overestimates EMG TOF ratio by 0.176...
ACG TOF 90% is not the same EMG TOF 90%

Is it possible to correct an ACG TOF ratio so that it can be used interchangeably with EMG?

- An ACG TOF ratio of at least 1.00 with an additional waiting period may be necessary to exclude residual NMB
- The waiting period would vary according to choice of relaxants and reversal drugs, patient age/gender, temperature, renal/liver function

EMG offers a better compromise than ACG with respect to the duration of calibration process and surrogate for the optimal time of tracheal intubation in children

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1) An Ipsilateral Comparison of Acceleromyography and Electromyography During Recovery from Nondepolarizing Neuromuscular Block Under General Anesthesia in Humans Sophie S. Liang, et al August 2013 • Volume 117 • Number 2 Anesth Analg
2) Comparison of clinical validation of acceleromyography and electromyography in children who were administered rocuronium during general anesthesia: a prospective double-blinded randomized study - Junk et al KJA Feb 2016 69(1): 21–26
Conclusion and take away

- Variety of management strategies for neuromuscular blockade and reversal efficacy. Anaesthesia societies guidelines still missing
- PORC is a recurrent silent enemy underestimated and patient hazard
- Still a lot of efforts on NMT education and NMT technology adoption needed
- Routine monitoring is not standard practice, but it improves patient safety when used systematically
- Antagonist dosage and injection time can be optimized with proper monitoring
- EMG can help measure accurately and precisely block levels and reversal. Several publications show superiority of EMG to other commercially available technologies

NMT: Neuromuscular transmission
PORC: Post operative residual curarization
EMG: Electromyography
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Important to use NMT correctly perioperatively. Users should always consult the monitor user manual for information and use of the NMT measurement. Contact your GE representative for the most current information.

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