Neuromuscular Monitoring and Patient Safety:

“Pulmonary Complications of Residual Block”

CEEA Course

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OVERVIEW

• Residual NM Paralysis – Incidence

• Standards & Magnitude of the Problem

• Myths & Dogmas - Pulmonary Effects

• Potential Solutions
Presynaptic Nerve Terminal

- Acetylcholine
- Ca$^{+2}$
- K$^{+}$

Reuptake

Vesicle

Exocytosis

Receptor

Postsynaptic Muscle

Normal NMJ
Non-Depolarizing Block

- = Acetylcholine

- = Non-Depolarizer
Depolarizing Block

○ = Acetylcholine
□ = Succinylcholine
PATTERNS OF STIMULATION

• Single Twitch
• Train-of-Four (TOF)
• Double Burst Stimulation (DBS)
• Tetanic Stimulation
• Post-Tetanic Count
Train-of-Four (TOF)

- **T<sub>1</sub>**
- **T<sub>2</sub>**
- **T<sub>3</sub>**
- **T<sub>4</sub>**

**Stimulus (mA)**

**Evoked Response**

- **100%**

**500 msec**

**T<sub>4</sub>/T<sub>1</sub> Ratio = 1.0**
TRAIN-OF-FOUR (TOF)

100%

EVOKE RESPONSE

500 msec

50%

PARTIAL BLOCK

STIMULUS (mA)

$T_1$ $T_2$ $T_3$ $T_4$

$T_4/T_1$ RATIO = 0.5
Definition of “Adequate Recovery”
Volunteer Data – healthy, no premedication

• **TOF > 0.70**
  • Open eyes, protrude tongue, 5-sec head lift
  • Cough, VC = 15-20 mL/kg *(Ali & Kitz 1973; Brand 1977)*

• **TOF < 0.80**
  • Impaired inspiratory flow/respiratory reserve *(Ali 1975)*
  • Decreased ventilatory response to hypoxia *(Eriksson 1996)*
  • Partial upper AW obstruction *(Eikermann 2003)*

• **TOF < 0.90**
  • Pharyngeal dysfunction *(Isono 1991)*
  • Increased risk of aspiration *(Eriksson 1997, 2000)*

• **TOF > 0.90**
  • Diplopia, fatigue
  • Not “street ready” *(Kopman 1997)*
Incidence of Residual Paralysis

• **Long-acting NMB:**
  • d-TC, pancuronium - **42%** (Neostigmine reversal)
    (Viby-Mogensen 1979; Beemer 1986; Brull 1989)

• **Intermediate-acting NMB:**
  • Incidence of residual weakness (TOF < 0.70):
    • Vecuronium – **7-64%**
      (Brull 1989; Bissinger 2000; Debaene 2003)
    • Atracurium – **4-65%**
      (McCaul 2002; Hayes 2001; Baillard 2005)
    • Rocuronium – **9-88%**
      (Kim 2002; Baillard 2005; Murphy 2005)

• **Short-acting NMB:**
  • Mivacurium – **23-35%**
    (Cammu, 2006)
Residual Block and Swallowing Ability

![Graph showing upper esophageal pressure in control and TOF conditions.](image)
Probability of Developing Postoperative Pulmonary Complications

Abdominal Surgery

Age

Postoperative Pulmonary Complications (%)

Pancuronium, TOF < 0.7
Pancuronium, Atracurium, and Vecuronium, TOF ≥ 0.7

Incidence of Residual Paralysis

- Meta-analysis – 24 studies; 3,375 patients
  - Antagonism in 62.1% of patients
  - Monitoring (qual. or quant.) – 24.4% patients
  - Intermediate-acting NMB:
    - Incidence TOF < 0.90 = 41%

- “Thus, four decades after the first nerve stimulators were described, unacceptable levels of residual paresis in the PACU continue to be reported.”

(Naguib, M. Br J Anaesth 2007)
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• Myths & Dogmas

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Are There Standards?

- **ASA:** no Standards, Guidelines or Statements
- “Standards for Basic Anesthesia Monitoring”
  (Effective July 2011)
  - Standard I – Presence of qualified anesthesia personnel
  - Standard II – Oxygenation
  - Standard III – Ventilation
  - Standard IV – Circulation
  - Standard V – Body Temperature
- “Statement on Documentation of Anesthesia Care”
  (Last amended October 22, 2008)
  - Silent
Houston, We Have a Problem

• Postoperative pulmonary complications
  (Moller 1990; Pedersen 1992; Berg 1997)

• Significant delays in meeting PACU and hospital discharge criteria (M&M, $$)
  (Murphy 2004)

• Appropriate reversal of NMB decreases 24-hr mortality and coma
  (Arbous 2005)
Houston, How Big Is the Problem?

- Incidence of Critical Respiratory Events = 0.8%
  - CRE = AW obstruction; $O_2$ sat 90-93% on $O_2$; $O_2$ sat <90% on $O_2$;
    Respiratory distress; Reintubation; Pulmonary aspiration. (Murphy 2008)

- Potential Risk: 0.8% of 10M = 80-100,000 patients/year with CRE

- Approximately 40M inpatient surgical cases/year (2006) in the United States
  - Nat Health Statistics Reports 11; 2009 (www.cdc.gov/nchs/data/nhsr)

- 60% receive GA = 24M (million) patients

- PORP = 41% then 10M patients at risk

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Truth of Fiction?
“Most anesthesiologists in the U.S. and Europe believe clinically significant residual postoperative weakness is RARE”

- In 2,636 completed surveys:
  - 64.1% of US anesthesiologists
  - 52.2% of European anesthesiologists
  - Believe postoperative residual weakness rate is <1%

TRUE! And they are WRONG!

Naguib M – Anesth Analg 2010;111:110
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(Naguib, M. Br J Anaesth 2007)
“Objective monitoring has a good applicability, but demands frequent use. There are many myths and excuses for not using a nerve stimulator. The truth is, however, that there are no good reasons for not monitoring neuromuscular block, whenever a neuromuscular blocking agent is given.”

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How Can We Improve Our Practice?

• Do not rely on **clinical tests** alone
  - Sensitivity (0.18-0.35) and Positive Predictive Value (0.47-0.52)

• Many clinical tests (leg- or head-lift, hand grip):
  - **Not specific for respiratory function:** 5-sec head-lift
  - 11 of 12 volunteers had sustained 5-sec lift, TOF ratio = 0.50
    (Eikermann M. Anesthesiology 2003)
  - 16 of 19 patients had 5-sec head-lift in PACU, TOF < 0.5
    (Pedersen T. Anesthesiology 1990)
How Can We Improve Our Practice?

- **Do not rely** on subjective (qualitative) tests
  - At TOF = 0.41-0.50:
    - Visual vs. Tactile detection of fade: p = NS
      (Viby-Mogensen J. Anesthesiology 1985)

- **Usefulness of Nerve Stimulators (PNS) is LIMITED**
  - Tactile evaluation vs. clinical assessment: p = NS (deep block)
    (Pedersen T. Anesthesiology 1990)
  - Meta-analysis: not able to demonstrate difference
    (Naguib M. Br J Anaesth 2007)
How Can We Improve Our Practice?

- Use **QUANTITATIVE** means of testing:
  - MMG, EMG, AMG, KMG or PMG
- Do NOT rely on time since last administration:
  - Single dose **vecuronium** 0.1 mg/kg
    - TOF < 0.75 at 3 hrs in 3 of 10 patients) – 30%
    - TOF < 0.75 at 4 hrs in 1 of 20 patients) – 5%
      (Caldwell JE. Anesth Analg 1995)
- Do NOT reverse **ALL patients** – may induce block
  - Neo induces weakness without NMB
    (Payne JP. Br J Anaesth 1980)
  - Neo impairs genioglossus & diaphragm
    (Eikermann M. Anesthesiology 2007)
How Can We Improve Our Practice?

- Timely ANTAGONISM (REVERSAL) - until TOF > 0.90
  - Neo 0.07 mg/kg after rocuronium:
    - From TOF count 1 - to recovery: 29 (9-76 min)
    - From TOF count 2 - to recovery: 23 (8-57 min)
    - From TOF count 3 - to recovery: 16 (7-44 min)
    - From TOF count 4 - to recovery: 10 (5-26 min)

- “A TOF count of 4 is needed to achieve reversal of rocuronium within 15 min!!”

(Kim KS. Anesth Analg 2004)
How Can We Improve Our Practice?

- **Reversal Dosing**
  - If TOF count = 0-1: DELAY reversal
  - If TOF count = 2-3: full reversal
  - If TOF < 0.40: full reversal
  - If TOF = 0.40-0.90: low-dose neo (0.02 mg/kg)
  - If TOF > 0.90 (quantitative): NO reversal

(Brull SJ, Murphy GS. Anesth Analg 2010)
In Summary:

• **Postoperative Neuromuscular Weakness is a Continuing Clinical Problem**

• **Objective Monitoring Will Ensure Pulmonary Recovery and Safety**

• **Standards Are Needed**
“Quality is not an act. It is a habit.”

Aristotle, 384-322 BCE. Philosopher, student of Plato, and teacher of Alexander the Great.

Thank You – Mulțumesc!