Clinical Article

Train-of-Four Results and Observed Muscle Movement in Children During Continuous Neuromuscular Blockade

Lisa Corso, RN, BSN, CCRN

PRIME POINTS

- Train-of-4 (TOF) test results are not reliable for predicting spontaneous muscle movement in children receiving neuromuscular blocking agents (NMBAs).

- Patients’ age, sex, or doses of sedatives, analgesics, or NMBAs are not significant factors.

- At 60 minutes after the start of the NMBA infusion, TOF results were predictive of spontaneous movement.

- Patients were less likely to move spontaneously as duration of the NMBA infusion increased.

- Clinical observation seems more accurate than TOF for gauging the level of paralysis in children.

Nondepolarizing neuromuscular blocking agents (NMBAs) have been used in intensive care units (ICUs) to augment medical treatment for many years. Medications such as vecuronium or cisatracurium, which are commonly used for long-term chemical relaxation in ICUs, bind to postsynaptic acetylcholine receptors but do not activate them (Figure 1).

After stimulation of a nerve, depolarization at the neuromuscular junction releases a flow of acetylcholine, which binds temporarily to the thousands of nicotinic receptors. The nicotinic receptors open sodium channels, which allow the stimulus to continue traveling through the muscle fibers and create a muscle contraction. Once each receptor has been activated, the acetylcholine is released and inactivated by acetylcholinesterase. Nondepolarizing NMBAs also bind temporarily to nicotinic receptors, blocking binding of acetylcholine there. Once 70% of the nicotinic receptors are filled by NMBAs, the receptors can no longer generate a contraction of the muscle fibers. NMBA infusion is often monitored by using peripheral nerve stimulation to determine the percentage of receptors at the neuromuscular junction blocked by NMBAs.

In a study by Foster et al, 75% of ICU nurses reported caring for patients who required continuous infusions of NMBAs. Common indications for NMBA infusion include facilitating mechanical ventilation and decreasing intracranial pressure after head injury (Table 1). It has been estimated that up to 10% of patients who receive an NMBA infusion for more than 24 hours may have residual muscle weakness. Vecuronium and pancuronium have active metabolites that build up...
after extended use, especially in the presence of inefficient elimination due to reduced hepatic or renal function.10 Prolonged muscle weakness may increase duration of ventilatory support and ICU length of stay, which in turn increase health care costs.4 NMBAs can have other complications that affect multiple body systems, which may be attributed to the inability of a patient to move.4,12 These risks increase with the severity of illness and length of time receiving NMBAs and include skin breakdown, peripheral edema, risk of aspiration, muscle atrophy, and corneal abrasions.3,4,8,12,14 All NMBAs can cause cardiac effects (tachycardia or bradycardia, vasodilatation) through histamine release, vagolysis, and sympathetic stimulation.4 Decreasing the amount of time of NMBA infusion and the amount of drug given may decrease complications and improve recovery after this regimen.2,9

In this article, I present a brief review of the literature on NMB use and monitoring, discuss NMB use in children, and describe a quality improvement project in which the degree of agreement between train-of-four (TOF) and observed muscle movement in patients cared for in the pediatric ICU was assessed.

Use of NMBAs in Children

The neuromuscular system is not completely developed at birth. The neuromuscular junction is immature in infants and continues to develop in the first 4 to 12 months of life.13,15-17 As acetylcholine receptors mature, the response to NMBAs becomes more varied, possibly because of the change from fetal to adult receptors and an increase in number and distribution of receptors.15,18,19 Odetola et al16 proposed that acetylcholine receptors scattered along muscle may alter NMBA binding in neonates. Myelination of nerve fibers continues through the first years of life, altering nerve conduction time.17,19

The effectiveness of any medication is a function of volume of distribution, ability to bind to receptors, and the efficiency of the breakdown/elimination processes.19,21 Infants have a larger extracellular fluid compartment than adults do, a situation that results in a larger

**Table 1** Common indications for use of neuromuscular blocking agents4

<table>
<thead>
<tr>
<th>Indication</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitate mechanical ventilation when sedation/analgesia is not effective</td>
<td></td>
</tr>
<tr>
<td>Decrease oxygen demands when capability for gas exchange is tenuous (as in acute respiratory distress syndrome)</td>
<td></td>
</tr>
<tr>
<td>Decrease intracranial pressure</td>
<td></td>
</tr>
<tr>
<td>Decrease pressure on surgical repair sites (ie, tracheal reconstruction or cardiac repairs)</td>
<td></td>
</tr>
<tr>
<td>Treat muscle spasms</td>
<td></td>
</tr>
</tbody>
</table>

*Based on McManus,4 Task Force of the American College of Critical Care Medicine,4 and Strange et al.4

**Author**

Lisa Corso is a unit-based educator in the pediatric intensive care unit at University of New Mexico Children’s Hospital in Albuquerque. She has worked in pediatric critical care for more than 15 years.

Corresponding author: Lisa Corso, RN, BSN, CCRN, University of New Mexico Children’s Hospital, 2211 Lomas Blvd NE, Albuquerque, New Mexico 87131 (e-mail: lcorso@salud.unm.edu).

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volume of distribution and relatively lower serum drug levels in infants.\textsuperscript{13,20,22} Drug metabolism through the kidneys and liver is less efficient in neonates, however, because of their immature elimination processes.\textsuperscript{21,23} The duration of action may therefore be prolonged in infants.\textsuperscript{15,16,21} This longer duration of action may lead to concerns about potentially changed neurological status when an infant does not respond as expected after the NMBA is withdrawn. Planned extubation or other changes in therapy may be delayed.

Children, on the other hand, have a higher ratio of muscle mass to fat than infants and adults, and as a result, children have relatively more acetylcholine receptors.\textsuperscript{13,21} As the muscle fibers and neuromuscular junction mature and the number of receptors increases as children grow, the required plasma concentration of an NMBA to produce the same degree of blockade as in an infant or adult also increases.\textsuperscript{21} This situation creates greater individual variation in response to NMBA. The net result of these differences is that the weight-indexed dosage requirements of NMBA are higher in children (age 1-10 years) than in infants or adults.\textsuperscript{13,25} In general, children recover neuromuscular activity more rapidly than do infants or adults.\textsuperscript{11} As a result, frequent observation is required, both to prevent inadvertent extubation and to evaluate the effects of movement on clinical status.

### Monitoring the Level of Blockade

The marked individual variation in response to NMBA makes it difficult to predict the onset, degree, and duration of neuromuscular blockade in a specific patient.\textsuperscript{13,24} Serum concentrations of NMBA do not necessarily reflect the amount of blockade present, so peripheral nerve stimulation is often used to monitor the degree of blockade.\textsuperscript{2,4,9} So far, the use of peripheral nerve stimulation to monitor dosages of NMBA has not been conclusively validated in any published studies,\textsuperscript{25} but the task force of the American College of Critical Care Medicine recommends assessment of the depth of neuromuscular blockade in ICU patients both clinically and through use of peripheral nerve stimulation.\textsuperscript{2,9} Such assessment allows the dosage of NMBA to be adjusted so that the lowest possible dose can be administered, thereby (we hope) reducing the risk of complications.\textsuperscript{2,4,9} Some physicians elect to allow patients to recover from the blockade every 24 to 48 hours (NMBA holiday)\textsuperscript{2,6,11,23} to determine whether continued blockade is necessary and to assess the patients’ need for additional sedation or analgesia.\textsuperscript{2,4,9} In order to measure TOF, 4 electrical stimuli are delivered to a peripheral nerve. When stimulated, the nerve causes a visible contraction of the corresponding muscle for each electrical impulse.

Administration of an NMBA blocks neuromuscular junctions, and by noting how many of the 4 electrical impulses cause a muscle twitch, the approximate percentage of acetylcholine receptor sites blocked can be assessed\textsuperscript{8,26} (Table 2). The level of blockade for optimal therapy is influenced by a patient’s overall condition and level of sedation; however, published reports suggest that 2 or 3 twitches are adequate in the ICU.\textsuperscript{2,4,8,9}

Because of its ease of access and superficial location, the ulnar nerve is often the standard first site stimulated for TOF testing.\textsuperscript{8,27} For this site, the distal electrode is placed over the proximal flexor crease of the wrist, in the ulnar groove. The second electrode is placed next to it (Figure 2). In order to ensure accurate placement, palpation or Doppler ultrasound can be used to locate the ulnar artery; the ulnar nerve is just adjacent. Stimulation of this nerve causes movement of the thumb and little finger.\textsuperscript{27} The facial nerve is another easily accessible option. For stimulation of this nerve, the first electrode is placed slightly above the point of the eyebrow, and the second electrode is placed over the facial nerve (Figure 3). Stimulation of this nerve causes twitching of the eyebrow or eyelid.

The choice of which nerve to use for TOF monitoring may be influenced by site accessibility, risk of false-positives, and edema.\textsuperscript{2,21}

### Table 2 Level of neuromuscular blockade as assessed with train-of-four testing\textsuperscript{a}

<table>
<thead>
<tr>
<th>No. of twitches</th>
<th>Approximate percentage of receptors blocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>75-80</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Based on Foster et al\textsuperscript{11} and Viby-Mogensen.\textsuperscript{26}
Peripheral edema can make TOF results inaccurate, making clinical observation more useful.\(^{13}\) Additionally, each muscle in the body has its own dose-response curve, and some of these curves differ markedly from one another.\(^{26,28}\) Producing the same degree of blockade in the diaphragm as in the muscles innervated by the ulnar nerve requires 60% to 80% more drug.\(^{2,26,28}\) This disparity suggests that even if no twitches are observed on the ulnar nerve during TOF testing, the diaphragm may not be completely paralyzed. If the treatment goal is to completely block any attempt at respiration, TOF monitoring may not be as useful as clinical observation.

**Quality Improvement Project in the Pediatric ICU**

My colleagues and I at the University of New Mexico Hospital in Albuquerque noted that the adult ICUs (medical ICU and trauma/surgical/burn ICU) and the pediatric ICU (PICU) differed in the use of peripheral nerve stimulation. The adult ICUs had protocols to titrate NMBA infusions on the basis of response to TOF, whereas the PICU had no titration protocols and rarely did TOF testing. This disparity led to some lively discussions about how neuromuscular blockade was assessed between medical staff who were accustomed to following TOF in the adult ICU or operating room and the PICU nursing staff who monitored muscle movement. As described in Peña et al,\(^{29}\) the nurses thought overwhelmingly that TOF results did not correlate well with neuromuscular blockade in children. Some patients moved, breathed, and coughed with no twitches, whereas others showed no movements with 4 twitches. Our current practice is to check the TOF every 12 hours while the patient is receiving NMBA; however, nursing staff relied more on clinical observation (eg, movement of fingers and toes, breathing, and coughing) to report patients’ response to NMBA infusions.
Initiation of an evidence-based nursing program provided an ideal opportunity to address the question of whether TOF testing was useful in our PICU patients. A project was launched to evaluate the reliability of TOF testing for assessing neuromuscular blockade in PICU patients. Two questions were addressed: (1) Can TOF results be used to predict whether or not the PICU patient will move? (2) What effects, if any, do age, sex, and medication dosages have on whether TOF results correlate with observed muscle movement? Because this project was a quality review of current practice, approval from the institutional review board was not necessary.

Method
This project was designed to determine the degree of correlation between clinical observation of muscle movement and TOF scores during and after continuous infusion of an NMBA. In order to ensure accuracy and consistency of testing, the project team members (2 registered nurses, 1 from each day and night shift, and the PICU unit-based educator) practiced proper placement of electrodes and use of the peripheral nerve stimulator and selected a standard voltage for each test (Innervator, model NS252J, Fisher & Paykel Healthcare Inc, Irvine, California). After several chemically paralyzed and sedated patients were tested at escalating voltages, 70 mA elicited twitches on most, so this was the standard voltage used for older children. Infants less than 1 year old were tested at 50 mA initially, with escalation to 70 mA if no response was noted.

Setting
The project took place in the 12-bed PICU of University of New Mexico Children’s Hospital in Albuquerque.

Sample
All children admitted to the PICU and receiving NMBAs between January 2003 and March 2004 were considered for the project. The project had no absolute exclusions; however, patients with diagnoses of pulmonary artery hypertension, increased intracranial pressure, or seizure disorders required approval of the attending physician to participate. After screening, 60 patients were eligible for the project. Of these, 13 had incomplete data collection, and 3 died, leaving a final group of 44 participants.

Staff Preparation
Staff nurses were educated on the plan and criteria, and a method was determined to access project team members at all times. Team members were present on duty most shifts and helped identify patients who met the criteria.

Data Collection
Approval was requested from attending physicians as needed. Demographic information was collected, and the data collection form was started. Patients were given test numbers (1, 2, 3, etc) to protect privacy, and only the appropriate number was displayed on the data collection form (several patients had 2 discrete episodes of neuromuscular blockade and were studied twice). Project team members served as data collectors, and each TOF test and physical stimulation required both the team member and a staff nurse at the bedside to validate movement or twitches noted.

Physical Stimulation
Observation for muscle movement was done during routine oral care or during suctioning of endotracheal or tracheostomy tubes. In intubated patients, oral care is critical to provide comfort, maintain membrane integrity, and decrease the oral flora that may lead to ventilator-associated pneumonia. Our practice is to use the sponge-stick or toothbrush with mouthwash or toothpaste to cleanse the oral cavity and teeth at least once every 8 hours. In chemically relaxed patients, mouth care includes suctioning secretions from the oral and nasal cavities. This process often creates a gag, cough, or struggle response if the patient is capable of responding. Suctioning of the endotracheal or tracheostomy tube is done as needed to maintain a clear airway. Frequency of suctioning is based on the buildup of mucus in the tube or lungs. After the patient is given oxygen, a sterile catheter is passed through the breathing tube, and suction is applied to remove secretions. This process elicits a cough (or abdominal muscle movement) if the patient is capable of responding. For purposes of this project, attempts to gag, cough, open the eyes, or movements of the abdomen, extremities, or digits were considered positive muscle movement.

Timing of TOF Testing
All patients received concurrent analgesia and sedation (fentanyl and lorazepam or midazolam). When continuous infusion of NMBA is
started, our current practice is to give a bolus of 1 hour’s worth of NMBA and immediately begin the infusion. This practice gives a therapeutic level of agent but does not necessarily create a steady state. The timing of TOF tests during the NMBA infusion ranged from a minimum of 90 minutes to several days after the start of the continuous infusion.

For maximal skin contact, the site was cleaned with alcohol or soap and water and then dried before electrode placement. The ulnar nerve served as the primary site, unless the patient had marked peripheral edema or both ulnar sites were inaccessible because of intravenous or arterial catheters or other reasons. The secondary site was over the facial nerve.

After coordination with the bedside nurse, the project team member did the initial TOF test (time 1). The method of physical stimulation (oral care or suction) was determined on the basis of which care was due at the time. Physical stimulation was completed, and the project team member and bedside nurse observed the patient for any movement. All observations and any additional comments were recorded on the data collection form, which was then placed in a special section of the bedside chart. The second observation (time 2) was made 60 minutes after the medication had completely cleared the intravenous tubing (time 3).

If the patient did not move and twitch at time 2, a third TOF test was done at 120 minutes after the medication had completely cleared the intravenous tubing (time 3).

Data Analysis

All raw data were compiled and taken to the hospital’s statistical analysis department for processing. TOF results and muscle movement were individually evaluated by using the Fisher exact square test and unconditional logistic regression for each testing time (SAS/STAT Version 8, SAS Institute Inc, Cary, NC). Factors included in the analysis were the patient’s age, sex, length of time receiving an NMBA, per-kilogram dose of NMBA, and per-kilogram doses of anxiolytic and analgesic medications. Analysis was based on the assumption that TOF scores of 0 to 2 with no muscle movement correlated and that TOF scores of 3 to 4 with muscle movement correlated. Our sample was split equally between infants (12 months and younger) and children (13 months and older), so we compared these 2 groups separately.

Results

The composition of the final group of patients is shown in Table 3. Patients’ ages ranged from newborn

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (50% of sample was ≤12 months old)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>6 days-12.5 years</td>
</tr>
<tr>
<td>Mean</td>
<td>25.5 months</td>
</tr>
<tr>
<td>Median</td>
<td>13 months</td>
</tr>
<tr>
<td>Sex, No. (%) of patients</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18 (41)</td>
</tr>
<tr>
<td>Female</td>
<td>26 (59)</td>
</tr>
<tr>
<td>Diagnosis, No. (%) of patients</td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>33 (75)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4 (9)</td>
</tr>
<tr>
<td>Trauma</td>
<td>4 (9)</td>
</tr>
<tr>
<td>Surgical</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Dosage of neuromuscular blocking agent, mg/kg per hour</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Mean</td>
<td>0.14</td>
</tr>
<tr>
<td>Hours of neuromuscular blockade</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>7-636</td>
</tr>
<tr>
<td>Mean</td>
<td>82.72</td>
</tr>
<tr>
<td>Dosage of anxiolytic, mg/kg per hour&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Range (SD)</td>
<td>0-0.68 (0.138)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.16</td>
</tr>
<tr>
<td>Dosage of analgesic, mg/kg per hour&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Range (SD)</td>
<td>0-15.25 (3.13)</td>
</tr>
<tr>
<td>Mean</td>
<td>3.45</td>
</tr>
</tbody>
</table>

<sup>a</sup> Four patients received a continuous infusion of analgesics and boluses of anxiolytics.

<sup>b</sup> One patient received a continuous infusion of anxiolytics and boluses of analgesics.
to 12.5 years old, and the group included patients with respiratory (83%), cardiac (1%), and other diagnoses (16%).

**Question 1: Can TOF Results Be Used to Predict Whether or Not a Patient Will Move?**

TOF results and spontaneous muscle movement results were compared for each testing time (Tables 4-6). TOF results were predictive of muscle movement only at time 2 (60 minutes after medication had completely cleared the intravenous tubing; \( P = .002 \)). Additionally, spontaneous movement results at time 1 were not predictive of spontaneous movement results at time 2.

**Question 2: What Effects, If Any, Do Age, Sex, and Medication Dosages Have on Whether TOF Results Correlate With Observed Muscle Movement?**

For each testing time, factors of sex and dosages of sedatives, analgesic agents, and NMBAs were compared independently with TOF results and with observations of spontaneous muscle movement; these factors were not statistically significant. A \( t \) test of spontaneous movement showed that significant factors were the patient’s age and length of time receiving the NMBAs infusion (the patient was less likely to move spontaneously as the duration of the NMBAs infusion increased). The likelihood of spontaneous muscle movement increased if the patient was 13 months or older. In the infant group, 10 of the 22 (45%) had a TOF of 4/4, but only 5 of those (23%) showed muscle movement. Regardless of age, 63% of children treated with NMBAs for 24 hours or more showed no muscle movement 60 minutes after discontinuation of the infusion. This lack of movement may have been due to a buildup of the active metabolite of vecuronium, which has a longer half-life than vecuronium itself.10

**Discussion and Review of Literature**

The literature has few data on use of peripheral nerve stimulation in PICUs. Many studies address use of NMBAs and TOF testing in the operating room, and extrapolating those data into the ICU is difficult. Peña et al29 studied the degree of agreement between TOF and observed muscle movement in a PICU. They found that during infusion, agreement of observations of muscle movement with results of TOF tests was poor, but after infusion was discontinued, agreement was substantial. This finding is in line with our results.

Several investigators10,15,16,30 described the effectiveness or recovery time from specific NMBAs in children. Reich et al10 compared cisatracurium and vecuronium in infants and neonates and found that TOF recovery time was longer with vecuronium, although neither extubation times nor ICU stays differed significantly between the 2 drugs. In studies5,11,31 in 3 adult ICUs, the researchers determined dosing requirements for comparing TOF and clinical observation. Baumann et al31 concluded that in adult patients receiving cisatracurium, TOF monitoring had no benefit over clinical assessment and thus TOF monitoring was unnecessary. Rudis et al32 compared dosage and recovery times in adult patients receiving vecuronium. They randomized patients to receive either TOF testing or assessment via clinical

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**Table 4 Time 1: During infusion (n = 44)**

<table>
<thead>
<tr>
<th>Twitches</th>
<th>No movement</th>
<th>Movement</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>25</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>3-4</td>
<td>10</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>9</td>
<td>44</td>
</tr>
</tbody>
</table>

Fisher exact \( P > .99 \)

<table>
<thead>
<tr>
<th>Correlation</th>
<th>n</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Predicted</td>
<td>28</td>
<td>64</td>
</tr>
<tr>
<td>Unpredicted</td>
<td>16</td>
<td>36</td>
</tr>
</tbody>
</table>

**Table 5 Time 2: 60 minutes after medication cleared tubing (n = 44)**

<table>
<thead>
<tr>
<th>Twitches</th>
<th>No movement</th>
<th>Movement</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>15</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>3-4</td>
<td>9</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>20</td>
<td>44</td>
</tr>
</tbody>
</table>

Fisher exact \( P = .002 \)

<table>
<thead>
<tr>
<th>Correlation</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted</td>
<td>32</td>
<td>73</td>
</tr>
<tr>
<td>Unpredicted</td>
<td>12</td>
<td>27</td>
</tr>
</tbody>
</table>
observation and found that the TOF group used less drug overall and recovered faster than the clinical observation group. In a literature review, Sparr et al. compared onset and duration of neuromuscular blockade with rapacuronium, rocuronium, and cisatracurium and included use in children.

### Limitations of the Project

This project was limited by the small convenience sample. Because 50% of the children were younger than 1 year old and the response to NMBAs in this age group is so variable, the results cannot be generalized to all children. Most (82%) of the infants studied were between 2 and 6 months old and required N MBA infusion for acute activity intolerance (decreased oxygen saturations with any movement). Although comparison between age groups of less than 1 year and more than 1 year showed the same lack of correlation between results of TOF tests and muscle movement, a larger study is needed to confirm these results.

A total of 80% of the TOF tests done at time 1 were done during the first 24 hours of N MBA infusion; the final 20% were done up to 5 days after the start of the infusion. Seven of the tests at time 1 were done before 4 hours, so although amount of N MBA was therapeutic, a steady state of NMBAs might not have been achieved. Tighter control over the timing of TOF testing during infusion would be beneficial to reduce the possibility of unstable drug levels.

Although we collected data on dose per kilogram of sedatives and analgesics, we did not determine total amounts given. Bedside nurses had the option of giving boluses of sedatives or analgesics if they decided that a patient was inadequately sedated.

Research team nurses were expected to judge, with the bedside nurse, the amount of peripheral edema present and therefore whether to use the ulnar or the facial nerve. This judgment added a subjective dimension to the choice of sites and may have skewed the results of TOF testing if the assessment of edema was in error.

Early in the project several patients were lost to follow-up because the team members were not notified when the infusion was discontinued. Therefore, labels were made for each patient’s infusion pump and nursing care kardex to remind nurses to notify a research team member when the infusion was discontinued. This adjustment, along with the nursing staff’s growing familiarity with the project, improved the completion rates.

For a related project, it would be useful to have titration parameters to keep TOF results at 2 twitches out of 4. Of special interest, patients receiving NMBAs for more than 24 hours could yield important information about the risk or benefit of longer N MBA therapy.

### Conclusion

The results of this quality improvement project indicate that TOF results in infants and children may not be reliable for predicting muscle movement during N MBA infusion. Clinical observation is key in gauging the level of paralysis. Additionally, because the reasons for a TOF test are to minimize the dosage of paralytics used and prevent the effects of prolonged paralysis, without titration parameters, routine TOF testing does not yield much useful information. Because of this lack of clear clinical benefit, investing the time and training required to ensure that correct TOF testing procedures are done by all staff nurses does not appear useful for our facility.

### Note:

According to the Critical Care Task Force (task force of the American College of Critical Care Medicine of the Society of Critical Care Medicine, the American Society of Health-system Pharmacists, and the American College of Chest

Physicians). TOF testing is both routine and recommended. TOF testing is the practice for both adult and pediatric patients who are managed with NMBAs.

Acknowledgments
Thank you to Terri Lancaster, RN, and Brian Nichols, RN, for continuing with the data collection in my absence. This project would not have been possible without the help of Matthias Buffle, RN, and Jeffrey A. O’Keefe, MD, for statistical analysis. This work was supported by the Department of Surgery at the University of New Mexico Hospital, and is in the public interest. Thank you to PICU manager Yvonne M. Gabaldon, RN, for all her support and encouragement with the writing and editing. Thank you to Mr Clifford Qualls, biostatistician at the University of New Mexico Clinical Research Center, for his assistance in writing and editing the results section. Thank you to Yvonne M. Gabaldon, RN, for her support and encouragement.

Financial Disclosures
None reported.

References
Learning objectives:
1. Recognize the rationale and mechanism of action underlying the use of neuromuscular blocking agents (NMBAs) in the critical care setting.
2. Explain variations in physiology that impact the effect of NMBAs in the pediatric population.
3. Describe the most accurate manner to evaluate neuromuscular blockade in pediatric critically ill patients.

1. Which of the following is a common indication for the use of neuromuscular blocking agents (NMBAs)?
   a. To decrease intracranial pressure
   b. To facilitate weaning from mechanical ventilation
   c. To increase muscle strength and coordination
   d. To increase oxygen demands and improve gas exchange

2. What method is commonly used to monitor the percentage of receptors blocked at the neuromuscular junction in the patient on NMBAs?
   a. Bispectral index monitoring
   b. Peripheral nerve stimulation
   c. Reflex arc testing
   d. Observation of response to painful stimuli

3. In approximately 10% of patients receiving NMBAs for more than 24 hours, which of the following may occur?
   a. Seizure activity
   b. Shortened duration of mechanical ventilation
   c. Diminished binding of NMBAs to the nicotinic receptors
   d. Prolonged muscle weakness

4. Which of the following is not a risk associated with prolonged use of NMBAs?
   a. Peripheral edema
   b. Muscle atrophy
   c. Bronchospasm
   d. Corneal abrasions

5. The weight indexed doses of NMBAs are larger in which of the following populations?
   a. Infants younger than 1 year of age
   b. Geriatric patients older than 70 years of age
   c. Adult patients from 18 to 60 years of age
   d. Children age 1 to 10 years

6. Which of the following statements is true regarding the physiology and ability of infants to metabolize drugs?
   a. Infants have smaller extracellular fluid compartments.
   b. Infants have less efficient drug metabolism through the kidneys and liver.
   c. Infants have a higher ratio of muscle mass as compared to children.
   d. Infants have more acetylcholine receptors.

7. Which of the following best describes the measurement of train-of-four (TOF)?
   a. Electrical stimulation of all 4 extremities is administered and results documented.
   b. Electrical stimuli are delivered in rapid sequence to a peripheral nerve.
   c. Four electrical stimuli are delivered at different times to a central nerve root.
   d. Electrical stimuli are delivered every 4 minutes to a peripheral nerve with results documented.

8. In patients undergoing successful neuromuscular blockade, what is the optimally suggested response to the TOF stimulation?
   a. 4 twitches
   b. 2 to 3 twitches
   c. 1 twitch
   d. 0 twitches

9. At the onset of the quality improvement project in the pediatric intensive care unit, what was the primary manner that the nurses assessed neuromuscular blockade?
   a. TOF measurement
   b. Peripheral nerve stimulation
   c. Monitoring of muscle movement
   d. Respiratory efficacy

10. At what time was observation for muscle movement done for the purpose of data collection in the 44 study participants?
    a. During endotracheal suctioning or routine oral care
    b. During assessment of response to painful stimuli or routine oral care
    c. During routine turning or dressing changes
    d. During NMBA holiday or endotracheal suctioning

11. Which of the following are the primary and secondary sites used for TOF measurement in the study participants?
    a. Radial and facial nerves
    b. Peroneal and ulnar nerves
    c. Ulnar and facial nerves
    d. Facial and spinal nerves

12. Which of the following is true regarding the relationship between TOF results and spontaneous muscle movement in the study participants?
    a. TOF measurement consistently predicted spontaneous muscle movement in the study participants.
    b. TOF measurement had no correlation to spontaneous muscle movement in the study participants.
    c. TOF results were predictive of spontaneous muscle movement only at 60 minutes following the start of NMBA infusion.
    d. TOF results were predictive of spontaneous muscle movement during initial infusion of the NMBA.

13. In this quality improvement process, what was found to be the key to gauging the level of paralysis in patients undergoing neuromuscular blockade?
    a. TOF measurement
    b. Spontaneous coughing
    c. Clinical observation
    d. None of the above
Train-of-Four Results and Observed Muscle Movement in Children During Continuous Neuromuscular Blockade
Lisa Corso

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