ORIGINAL CLINICAL RESEARCH REPORT

Pediatric Intraoperative Electromyographic Responses at the Adductor Pollicis and Flexor Hallucis Brevis Muscles: A Prospective, Comparative Analysis

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BACKGROUND: Peripheral nerve stimulation with a train-of-four (TOF) pattern can be used intraoperatively to evaluate the depth of neuromuscular block and confirm recovery from neuromuscular blocking agents (NMBAs). Quantitative monitoring can be challenging in infants and children due to patient size, equipment technology, and limited access to monitoring sites. Although the adductor pollicis muscle is the preferred site of monitoring, the foot is an alternative when the hands are unavailable. However, there is little information on comparative evoked neuromuscular responses at those 2 sites.

METHODS: Pediatric patients undergoing inpatient surgery requiring NMBA administration were studied after informed consent. Electromyographic (EMG) monitoring was performed simultaneously in each participant at the hand (ulnar nerve, adductor pollicis muscle) and the foot (posterior tibial nerve, flexor hallucis brevis muscle).

RESULTS: Fifty patients with a mean age of 3.0 ± standard deviation (SD) 2.9 years were studied. The baseline first twitch amplitude (T1) of TOF at the foot (12.46 mV) was 4.47 mV higher than at the hand (P <.0001). The baseline TOF ratio (TOFR) before NMBA administration and the maximum TOFR after antagonism with sugammadex were not different at the 2 sites. The onset time until the T1 decreased to 10% or 5% of the baseline value (T1) was delayed by approximately 90 seconds (both P =.014) at the foot compared with the hand. The TOFR at the foot recovered (TOFR ≥0.9) 191 seconds later than when this threshold was achieved at the hand (P =.017). After antagonism, T1 did not return to its baseline value, a typical finding with EMG monitoring, but the fractional recovery (maximum T1 at recovery divided by the baseline T1) at the hand and foot was not different, 0.81 and 0.77, respectively (P =.68). The final TOFR achieved at recovery was approximately 100% and was not different between the 2 sites.

CONCLUSIONS: Although this study in young children demonstrated the feasibility of TOF monitoring, interpretation of the depth of neuromuscular block needs to consider the delayed onset and the delayed recovery of TOFR at the foot compared to the hand. The delay in achieving these end points when monitoring the foot may impact the timing of tracheal intubation and assessment of adequate recovery of neuromuscular block to allow tracheal extubation (ie, TOFR ≥0.9). (Anesth Analg 2024;139:36–43)

KEY POINTS

- **Question:** Are the electromyographic (EMG) responses from the adductor pollicis (hand) and flexor hallucis brevis (foot) muscles equivalent in pediatric patients?
- **Findings:** The onset of neuromuscular block and recovery after antagonism with sugammadex were delayed at the foot compared to the hand.
- **Meaning:** When using the foot as an alternative site to the hand for quantitative EMG monitoring in pediatric patients, delays at the foot in neuromuscular block onset and recovery need to be considered when timing laryngoscopy and tracheal extubation, respectively.

Neuromuscular blocking agents (NMBAs) remain an integral component of intraoperative care to facilitate tracheal intubation and to provide skeletal muscle relaxation for surgical exposure. The importance of monitoring the response to and recovery from NMBAs using quantitative

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DOI: 10.1213/ANE.0000000000006926

Accepted for publication December 28, 2023.

Funding: None.

Conflicts of Interest: See Disclosures at the end of the article.

Reprints will not be available from the authors.

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train-of-four (TOF) devices has recently been highlighted by the American Society of Anesthesiologists (ASA) and the European Society of Anaesthesiology and Intensive Care Practice Guidelines.[1] Current recommendations include the use of quantitative neuromuscular monitoring of the adductor pollicis muscle and confirmation of recovery of the TOF ratio (TOFR) to ≥0.9 before tracheal extubation. In clinical practice, muscle responses to TOF stimulation may be evaluated qualitatively using a subjective visual count of the muscle twitches in response to stimulation by a peripheral nerve stimulator, but, preferably, responses should be assessed quantitatively by a device that measures the extent of recovery of neuromuscular function. Quantitative measurement allows for objective criteria including not only the number of twitches in the TOF sequence (TOF count, or TOFC) but also the calculation of the TOFR by measuring the individual response of the fourth and first twitch heights and calculating their ratio (T4/T1 ratio or TOFR).[2–4]

Quantitative technology for TOF monitoring includes mechanomyography, acceleromyography, or electromyography (EMG). Given the inaccuracy of visual inspection (qualitative assessment) and with the support of the recent ASA guidelines, there has been increased use of quantitative devices during intraoperative care of adults.[5–7] However, this nascent practice change has not yet occurred in infants and children.[8] Cited reasons for failure to monitor neuromuscular block in infants and children have included a lack of reliable monitors for use in this population, the potential impact on clinical productivity due to the time required to apply the devices, and challenges with calibration of existing acceleromyographic monitors.[9,10] Additionally, acceleromyography can generally only be used when the target muscle (eg, the adductor pollicis muscle) can move freely to allow accurate measurement of the twitch responses. This measurement may not be feasible when the arm is tucked under surgical drapes, at the patient's side, or when the upper extremities are being used for placement of other vascular devices or monitors.[11,12]

EMG-based devices may allow quantitative monitoring of neuromuscular block despite restricted access to the extremity.[13,14] These devices do not require muscle movement; rather, the muscle response is assessed by measuring the amplitude of the individual EMG responses (compound muscle action potentials [cMAPs]). To date, there are limited data on EMG-based TOF monitors in pediatric patients. However, access to the upper extremity for sensor placement may still be limited in specific clinical scenarios, thereby precluding monitoring of the adductor pollicis muscle, the site currently recommended by the ASA guidelines.[1] The current study evaluated the feasibility of recording cAMPs from the lower extremity and compared paired responses from the foot and the hand in pediatric patients undergoing surgical procedures requiring the administration of an NMBA.

METHODS

This study was approved by the Institutional Review Board of Nationwide Children's Hospital, Columbus, OH. The trial was registered before patient enrollment at www.clinicaltrials.gov (NCT04475250, principal investigator: J. D. Tobias, MD, date of registration: July 16, 2020). Written informed consent was obtained from a parent or legal guardian, and assent was planned for patients who were ≥9 years of age (although not secured since all patients were younger than this threshold).

Eligibility and Study Location

Pediatric patients less than 18 years of age who were having a surgical procedure requiring the administration of an NMBA were eligible for enrollment. Exclusion criteria included a history of a peripheral neurologic, myopathic, or neuropathic disease, peripheral edema, or patients in whom access to an upper and lower extremity was not available for monitor placement. Eligible patients were identified in the preoperative holding area on the day of surgery. All anesthetics were administered at Nationwide Children's Hospital and patient enrollment was from February 13, 2023, through May 20, 2023.

Study Design

Quantitative EMG monitoring of the response to the administration of NMBAs was performed using the TetraGraph monitor (Senzime AB). Two separate monitors were used, 1 placed on the hand and the other on the foot (Figure) to allow for paired comparisons within each patient. After inhalation induction of general anesthesia, the skin was prepped with an alcohol swab, and the specially designed pediatric recording electrodes (TetraSens Pediatric) were applied. Anesthesia was maintained with sevoflurane. For hand monitoring, the stimulating electrodes were placed over the ulnar nerve and the recording electrodes over the adductor pollicis muscle with the reference electrode on the thumb (Figure, upper panel). For foot monitoring, the stimulating electrodes were placed over the posterior tibial nerve, and the recording electrodes over the flexor hallucis brevis muscle and the great toe (Figure, lower panel). After sensor placement, the electrodes were connected to the device cable. TOF responses were obtained at 20-second intervals thereafter until extubation. The internal clocks of the devices were adjusted to the same time in hours and minutes as that on the electronic

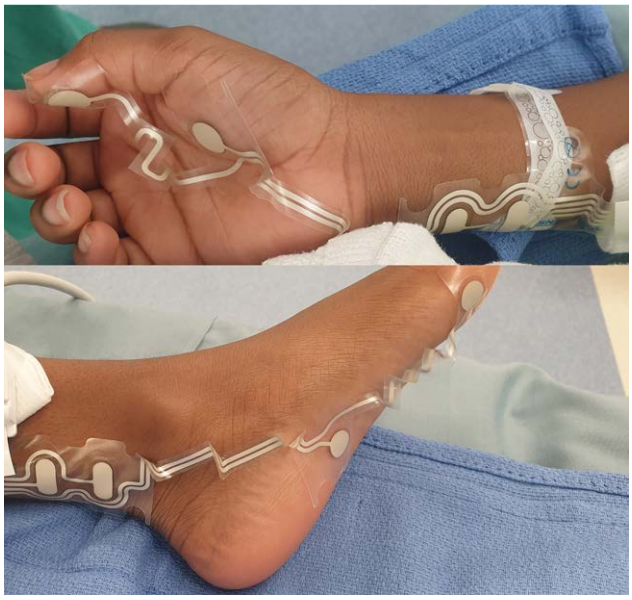

Figure. Application of the TetraSens Pediatric (Senzime AB) sensors on a child who participated in the study. For monitoring at the hand (top panel), the stimulating electrodes were placed over the ulnar nerve and the recording electrodes over the adductor pollicis muscle with the reference electrode on the thumb. For monitoring at the foot (bottom panel), the stimulating electrodes were placed over the posterior tibial nerve, and the recording and reference electrodes over the flexor hallucis brevis muscle and the great toe, respectively.

medical record corresponding to the patient being monitored. The output from the devices was recorded by the monitor in its internal, nonvolatile memory.

Intraoperative anesthesia management, including the choice of anesthetic agents and the dose of NMBA and antagonist, was at the discretion of the attending pediatric anesthesiologist. Anesthesia providers were not blinded to the display from the TetraGraph, which included the TOFR and the TOFC, where relevant. According to our usual institutional clinical practices, rocuronium was primarily used for neuromuscular block and sugammadex for antagonism.

Data Extraction

The raw, binary data files, including the digitized waveforms, for each patient were securely uploaded to a server maintained by the manufacturer using the TetraConnect (Senzime AB) software and then downloaded into a CSV format. These files contained the time that recording started, and for each stimulation event, the offset in seconds from the start of data recording, the mode of stimulation (eg, TOF, single twitch, tetanic stimulation), and the amplitude of the compound motor action potential (cMAP), if detected, for each twitch.

The threshold used for determining whether a cMAP was valid in the monitors' software version was 0.4 mV; if the amplitude was <0.4 mV, that response was not counted as a valid cMAP. For each TOF stimulus sequence, the TOFC and, if 4 valid cMAPs were detected, the TOFR were calculated. Each of the 2 files (1 from the hand and 1 from the foot) from each patient was combined in an Excel (Microsoft) workbook, and only responses corresponding to a TOF sequence were used for analysis. Thus, responses to a tetanic stimulus were not included, nor were the single twitch responses used to establish the supramaximal current during the initial device calibration process. Because the recording timestamps from the hand and foot were different for each patient (eg, the 2 devices were not started simultaneously, or the clocks were different by several seconds), the offset times for the foot recording were adjusted by the difference between the 2 start-of-recording timestamps. As an example, if the TetraGraph recording from the hand was started at 09:00:00 and the TetraGraph at the foot was started at 9:00:17, then 17 seconds were added to the incremental times recorded at the foot. This adjustment resulted in the alignment of the interval times for both devices to the identical clock time, allowing for a paired analysis of the data. For each patient and each recording location, the control (baseline) T1 amplitude (T1c) before the administration of the NMBA was measured, along with the baseline TOFR. Also, the final TOFR was determined at each site (hand and foot) along with the TOFR at the foot when the TOFR at the hand first recovered to ≥0.9 and the TOFR at the hand when the TOFR at the foot first recovered to ≥0.9.

We calculated the fractional depression of the T1 by dividing the T1 by the T1c (T1/T1c) and noted the TOFC reported at each timestamp in the data file. We determined the difference in the onset of the neuromuscular block after administration of the NMBA between the hand and the foot as the difference between the adjusted incremental times when the TOFC first reached 0 and when the T1/T1c reached 0.10 or 0.05 (ie, 90% or 95% T1 depression, respectively).[15] The statistical significance of the means of those paired differences compared to 0 seconds (the null hypothesis for a paired *t*-test) was calculated using a 2-sided 1-sample t-test. We were not able to calculate accurately the actual onset interval from the initial administration of the NMBA because the timestamps for those events were taken from the electronic health record (EHR), which rounds times to the nearest minute. Additionally, there can be substantive errors in the attributed time due to delays until the anesthesia providers manually record the doses in the EHR. For example, in some patients' EHRs, the time manually ascribed to the administration of the initial dose of rocuronium was after the TOFC had already reached 0. For similar reasons, the interval from the time of sugammadex administration to reaching a TOFR ≥0.9

could not be determined accurately. Therefore, we assessed the apparent differences in recovery times when measured between the 2 recording locations as the interval from when the TOFR at the hand first was ≥0.9 and when it first reached ≥0.9 at the foot. As above, we used a 2-sided 1-sample t-test to compare the means of the paired differences of the recovery times to 0 seconds. We also compared the fraction of patients who had a TOFR ≥0.9 at the foot at the first time that the TOFR was ≥0.9 at the hand. Conversely, we also compared the fraction of patients who had a TOFR ≥0.9 at the hand at the first time that the TOFR was ≥0.9 at the foot. We compared the data from the 2 sites when measurements from both sites were available at approximately the same time (ie, within 20 seconds of each other). For example, monitoring was often discontinued before the TOFR reached 0.9 at the foot because the TOFR at the hand had already reached 0.9, and the patient's trachea had been extubated. The recovery TOFR was determined for patients in whom the TOFR had stabilized.

Statistical Analysis

The primary end point was a comparative evaluation of the paired responses within patients at baseline and neuromuscular function recovery from the EMG devices placed on the hand and the foot. Continuous demographic data were summarized and presented as the mean ± SD. Categorical variables were presented as numbers and percentages. We used descriptive statistics and a paired 2-sided *t*-test to compare the various measurements of neuromuscular block between the 2 sites. The differences between the number of patients with a TOFR ≥0.9 at the foot when the TOFR was ≥0.9 at the hand (and vice versa) were assessed by the proportions test. *P* values <.05 were considered statistically significant.

The calculated sample size was 24 to be able to detect a 3% difference between the 2 sites in the baseline TOFR, assuming a standard deviation (SD) of 0.05, with α = .05 and power = 0.8. The values were based on the SD of 0.03 and baseline TOFR of 100% obtained during a pediatric study of the TetraGraph previously published by the study group.[14] Additional patients were enrolled to account for potential technical failures in obtaining the data.

RESULTS

The study cohort included 50 patients ranging in age from 3 months to 7.9 years (mean 3.0 ± SD 2.9 years) and in weight from 3.7 to 40.0 kg (mean 13.7 ± SD 8.8 kg) (Table 1). The baseline T1 (12.46 mV) was higher at the foot than the hand by an average of 4.47 mV (*P* <.0001, Table 2). The TOFR at baseline (before the administration of an NMBA) and the maximum TOFR achieved were not different at the hand versus the foot (Table 3). The onset time of the change in the T1 amplitude to either 10% or 5% of the baseline T1 amplitude was delayed at the foot compared to the hand by approximately 90 seconds (Table 3). The recovery time to a TOFR ≥0.9 at the foot after it had already reached a value of 0.9 at the hand was approximately 3 minutes (Table 3). Among the 22 patients with corresponding data pairs from both the hand and the foot, when the TOFR was ≥0.9 at the hand, only 6 of 22 patients had a TOFR of ≥0.9 at the foot (Table 4). Conversely, in the 17 patients who achieved a TOFR ≥0.9 at the foot, the corresponding TOFR at the hand was already ≥0.9 in 15 of 17 patients. Therefore, recovery of the TOFR at the foot more reliably predicted recovery at the hand, but not vice versa. As has been noted in previous studies using quantitative TOF monitoring at the hand, the mean T1 after reversal of neuromuscular block with sugammadex may not return to the baseline T1c or may be delayed compared with the return of the TOFR to baseline.[14,16,17] At the hand, recovery of T1 was 81%, and at the foot, it was 77% of baseline (paired difference *P* = .68). The mean final TOFR achieved was approximately 1.0 and was not statistically different between the 2 monitoring sites (Table 3).

Table 1. Demographic Data of the Study Cohort

Variable	Value
Number enrolled	50
Age, y, mean (SD)	3.0 (2.9)
Weight, kg, mean (SD)	13.7 (8.8)
BMI, kg/m^2, mean (SD)	16.6 (2.7)
ASA physical status, n (%)	
I	10 (20%)
II	32 (64%)
III	8 (16%)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.

DISCUSSION

In general, application, intraoperative use, and the ability to measure EMG responses to TOF stimulation were similar between the hand and the foot. However, there were also some important differences.

First, the baseline T1 was higher at the foot than at the hand by an average of 4.47 mV. The implication is that the TOFC may be greater when measuring at the foot than at the hand because cMAP values greater than the 0.4 mV threshold will persist longer. For example, suppose the baseline T1 was 5 mV at

Table 2. Neuromuscular Block Monitoring at the Hand Versus the Foot

Parameter[a]	Number of paired comparisons[b]	Hand	Foot	Difference (hand-foot)	*P* value
T1 (baseline), mV, mean (95% CI)	41	7.99 (6.17–9.27)	12.46 (10.82–14.10)	-4.47 (−6.21– −2.74)	<.0001
TOFR (baseline), mean (95% CI)	41	0.97 (0.95–0.99)	0.99 (0.97–1.01)	-0.017 (−0.043–0.0097)	.21
T1 (recovery)/T1c, mean (95% CI)	23	0.81 (0.67–0.94)	0.77 (0.71–0.84)	0.035 (−0.14– −.21)	.68
TOFR (recovery), mean (95% CI)	27	1.02 (0.99–1.06)	0.98 (0.93–1.02)	0.045 (−0.0079–0.98)	.092

Abbreviations: CI, confidence interval; mV, millivolts; T1, amplitude of the first twitch following train-of-four stimulation; T1c, control amplitude of the T1; TOFR, train-of-four ratio.

[a]Baseline values were taken before the initial administration of a neuromuscular blocking agent. Recovery values were the highest stable measures recorded after antagonism of neuromuscular block with sugammadex. If the values had not reached a plateau at the time that data recording was discontinued, those patients were not included in the analysis. These exclusions occurred almost exclusively for the measurements at the foot, a consequence of the delayed recovery of the TOFR at that site compared to the hand. In such cases, recovery had already occurred to at least 0.9 at the hand. This issue was not recognized until after the data had been analyzed.

[b]The number of patients is less than the number enrolled (n = 50) because there were not always corresponding data from the 2 sites. For example, if there were a failure to record data due to technical reasons or cessation of recording before the corresponding end point was reached, paired data might be missing.

the hand and 10 mV at the foot, with the TOFR = 1.0 at both sites. At the hand, the TOFC would reach 3 when the fourth twitch in the TOF decreased to just below 8% of its initial value (ie, the fourth twitch would not be counted as a valid cMAP because the voltage was <0.4 mV). However, at the foot, the same 8% decrease would result in a fourth twitch amplitude of 0.8 mV and would be counted. The etiology of the higher mean baseline amplitude at the ankle is unclear.

Second, the block onset time, as assessed by T1 depression from baseline, was delayed at the foot compared to the hand by approximately 90 seconds. This latency may be attributed, among other factors, to longer circulation time to the foot than to the hand (and thus, delayed delivery of NMBA to the foot) and to different foot muscle sensitivity to NMBA effects compared with the hand muscles.[18] We did not evaluate conditions for tracheal intubation or correlate them with twitch depression on the 2 monitors because our aim was to determine whether monitoring of neuromuscular responses was feasible using EMG in this nerve/muscle arrangement in pediatric patients. However, such future study is important for optimal timing of intubation when using quantitative EMG monitoring at the foot. If tracheal intubation were timed according to T1 depression at the foot, it would be reasonable to assume that waiting the extra 90 seconds (compared with T1 depression information from the hand) would result in similar or better intubating conditions, as the extra time may result in a deeper block. We therefore postulate that the conditions might be equivalent or better for the same degree of twitch depression when measured at the foot compared to the hand. The reason is that the extent of the block measured at the foot underestimates that at the hand and the criteria are based on monitoring the adductor pollicis muscle responses.

Third, the recovery time from sugammadex administration to recovery of TOFR ≥0.9 at the foot was delayed by approximately 3 minutes compared with the hand. If clinicians apply the ASA guidelines that call for extubation only when the TOFR has recovered to at least 0.9 but base this adequate recovery on TOFR responses obtained from the foot rather than on responses from the adductor pollicis, tracheal extubation would be delayed. There would be a delay because the threshold of TOFR ≥0.9 is reached earlier at the hand, which is the site recommended by the ASA guidelines. From a patient perspective, however, timing tracheal extubation based on the TOFR at the foot may introduce a greater level of safety.[19] These extra 3 minutes may allow additional recovery of neuromuscular function since at a TOFR >0.9, more than 75% of the postsynaptic receptors are still blocked,[20] and the ventilatory response to hypoxia at this level of recovery is still blunted.[21] This potential increase in patient safety must be weighed against the additional 3-minute delay in operating room times.

Previously published reports of neuromuscular monitoring in adult patients have demonstrated generally similar results comparing onset at the foot versus the hand.[22–24] Using acceleromyography, Le Merrer et al[22] demonstrated that the time to achieve

Table 3. Differences Between the Foot and the Hand for Onset and Recovery Parameters

Parameter	Number	Difference between foot and hand, seconds, mean (95% CI)	*P* value
Onset to TOFC = 0	41	37.1 (4.4–60.8)	.027
Onset to T1/T1c = 0.10 (90% T1 depression)	41	89.4 (19.59–159.3)	.014
Onset to T1/T1c = 0.05 (95% T1 depression)	41	92.1 (20.7–163.5)	.014
Interval from TOFC = 0.9 at hand to TOFC = 0.9 at foot	14[a]	191.4 (38.5–343.3)	.017

Abbreviations: T1, amplitude of the first twitch after train-of-four stimulation; T1c, control amplitude of the T1; TOFC, train-of-four count; TOFR, train-of-four ratio;.

[a]The number of comparisons was less than 41 because monitoring at the foot was usually discontinued before the TOFR reached 0.9. Truncation of data recording was a consequence of the faster recovery of the TOFR to 0.9 at the hand.

Table 4. Number of Subjects Suitable for Tracheal Extubation Based on TOFR ≥0.9

Time of the comparison (n)	Number of patients where the TOFR at the hand ≥0.9	Number of patients where the TOFR at the foot ≥0.9	*P* value
TOFR at hand first recovered to ≥0.9 (22)	22	6	<.0001
TOFR at foot first recovered to ≥0.9 (17)[a]	15	17	.62

Abbreviation: TOFR, train-of-four ratio.

[a]The number of simultaneous measurements at the foot was less than that at the hand because monitoring at the foot was sometimes discontinued before the TOFR reached 0.9, precluding comparison.

a TOFC = 0 was 0.7 minutes slower at the foot. Using kinemyography, Kern et al[23] also showed a delayed onset to a TOFC of 0 at the foot, lagging by 1.2 minutes. Using EMG, Sopher et al[24] showed no statistical difference between the onset time from initial NMDA administration to 100% T1 depression (ie, TOFC = 0). However, that study was grossly underpowered and the probability of a type I error was high.[24]

Unfortunately, methodologic differences in the previous studies preclude meaningful comparison of the delayed recovery times after pharmacologic antagonism in the current study. In the Lederer et al's study, the times to recovery to a TOFC = 4 after antagonism were measured from the time of initial administration of the NMDA, not from the time of antagonism. In the Kern et al's[23] study, patients were allowed to recover spontaneously to a TOFR = 0.75, rather than after pharmacologic antagonism. In the Sopher et al's[25] study, recovery only to a TOFR = 0.75 was assessed after edrophonium, a drug that may not result in full pharmacologic recovery.

Clinical practice in pediatric anesthesia has not generally emphasized the need for monitoring of neuromuscular block. In recent years, the addition of sugammadex to the pharmacologic armamentarium and its faster and more effective reversal of neuromuscular block, especially deep block, after neostigmine, has led to a debate about whether quantitative neuromuscular monitoring is necessary.[26] This debate, coupled with several factors that may impact the feasibility of quantitative monitoring in infants and children, has led to limited use of this technology in pediatric patients.[8] However, our previous studies have demonstrated the feasibility of using EMG-based quantitative TOF monitors even in infants less than 10 kilograms.[13,14] Pediatric quantitative neuromuscular monitoring has been made easier by the availability of pediatric-sized sensors.

Our study focused on determining whether monitoring of NMBA onset and recovery times at the foot might be an alternative to using the adductor pollicis muscle at the hand. Since the results of our study suggest that such neuromuscular monitoring is feasible at the foot, future studies should validate our findings and, more importantly, should establish the time relationships between responses at the hand and foot during all phases of neuromuscular block, including moderate, deep, and intense block.[2]

Limitations and Strengths

A limitation of the study was that we were unable to accurately determine block onset times from the first administration of the NMBA due to inaccuracy in recording the time, rounding of time entries in the EHR, and the inability to synchronize the devices and the EHR to the nearest second. Nonetheless, we were able to accurately determine the relative difference between the 2 sites by adjusting the clock times in the recorded data. For future studies, we recommend having a study coordinator record the times concurrently using an external clock with accuracy to the nearest second rather than relying retrospectively on the EHR. Another limitation was introduced by the time pressures intrinsic in a busy operating room, and the inability to ensure that neuromuscular monitoring and calibration of the monitors always preceded the administration of NMBAs. Although this time pressure did prevent the collection of all the data that we had planned to measure onset times, this is not clinically relevant because multiple sites are not monitored during routine anesthetics. We were able to record data from at least 1 of the 2 sites in all patients. Coupled with results from a previous study demonstrating that the median time to place, connect, and calibrate the EMG sensors for the studied device was 62 seconds,[27] our results demonstrate that routine quantitative monitoring is possible even in a busy anesthesia practice and that when neither hand is available, the foot is an acceptable alternative site.

Results may not be generalizable to adults or children older than 8 years as the oldest patient enrolled was 7.9 years. Also, because patients with peripheral edema or underlying peripheral neurologic, myopathic, or neuropathic disease were excluded, results may also not apply to those patient populations. Therefore, additional study in these groups is recommended to determine if similar delays in onset of and recovery from neuromuscular block are applicable.

Strengths of the study include a wide range of patient ages and near-simultaneous monitoring of the hand and foot in each patient, allowing for paired data analysis in a novel comparison of evoked neuromuscular responses from hand and foot in pediatric patients.

CONCLUSIONS

Quantitative EMG-based TOF monitoring at the foot of infants and children can help clinical care align

with the recently introduced practice guidelines for monitoring of neuromuscular block in adult patients if the hand is not available for neuromuscular monitoring. Although the ulnar nerve and adductor pollicis muscle remain the recommended site, alternative sites may be required due to patient positioning, surgical draping, surgical procedure, or the use of the upper extremity for other invasive and noninvasive monitoring devices. The EMG-based quantitative monitor functioned effectively on the lower extremity, but there were potentially clinically relevant differences when compared to results from the hand, including slower onset and recovery times. These differences need to be considered when interpreting the information from the monitor. Additional studies correlating the neuromuscular response at the foot with conditions for tracheal intubation and extubation are needed to develop recommendations on the timing of these events.

ACKNOWLEDGMENTS

Senzime AB provided the sensors and monitors used in this study without charge and assisted with retrieval of the data from the monitors.

DISCLOSURES

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Contribution: This author helped in conceptualization, funding acquisition, methodology, project administration, resources, supervision, visualization, writing—original draft preparation, and writing—review and editing.
Conflicts of Interest: None.
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Conflicts of Interest: None.
Name: Julie Rice-Weimer, RN.
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Conflicts of Interest: None.
Name: Sibelle Aurelie Yemele Kitio, MS, MPH.
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Conflicts of Interest: None.
Name: Sorin J. Brull, MD, FCARSCI (Hon).
Contribution: This author helped in conceptualization, funding acquisition, methodology, resources, visualization, writing of the review, and editing.
Conflicts of Interest: Dr S. J. Brull has intellectual property assigned to Mayo Clinic; is a consultant for Merck & Co., Inc.; is a principal, shareholder, and chief medical Officer in Senzime AB (publ); and an unpaid member of the Scientific/Clinical Advisory Boards for The Doctors Company, Coala Life Inc., NMD Pharma, and Takeda Pharmaceuticals.
Name: Sidhant Kalsotra, MD .
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Conflicts of Interest: None.

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