ANESTHESIOLOGY

Comparison of Contralateral Acceleromyography and Electromyography for Posttetanic Count Measurement

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Deep neuromuscular blockade during anesthesia for laparoscopic or robotic surgeries may offer several advantages in terms of patient outcomes and physician surgical experience
- Posttetanic count can be used to identify intense neuromuscular block (posttetanic count equal to 0) and deep neuromuscular block (posttetanic count greater than or equal to 1 and train-of-four count equal to 0) and estimate the time to recovery

What This Article Tells Us That Is New

- The agreement of posttetanic counts monitored in contralateral arms by acceleromyography and electromyography was determined in 35 patients given 0.6 mg/kg rocuronium after induction of anesthesia and calibration of the monitors, with additional doses of 0.3 mg/kg if required
- Seventy-three percent of 226 pairs of acceleromyography– and electromyography–posttetanic count measurements indicated the same neuromuscular blockade status (intense or deep block)
- Of 184 pairs of posttetanic counts of 15 or less, 42 (23%) acceleromyography–posttetanic counts were equal to electromyography–posttetanic counts, 93 (50%) were more than electromyography counts, and 49 (27%) were less than electromyography counts

ABSTRACT

Background: Electromyography has advantages over mechanomyography and acceleromyography. Previously, agreement of the train-of-four counts between acceleromyography and electromyography was found to be fair. The objective of this study was to assess the agreement of posttetanic count including agreement of neuromuscular blockade status (intense block, posttetanic count equal to 0; or deep block, posttetanic count 1 or greater and train-of-four count equal to 0) between acceleromyography and electromyography.

Methods: Thirty-six patients, aged 20 to 65 yr, participated in this study. A dose of 0.6 mg/kg rocuronium, with additional dose of 0.3 mg/kg if required, was administered to the patients. The train-of-four and posttetanic counts were monitored in the contralateral arm using electromyography at the first dorsal interosseus or adductor pollicis, and acceleromyography at the adductor pollicis. Posttetanic count measurements were performed at 6-min intervals; the responses were recorded until the train-of-four count reached 1. The authors evaluated the agreement of degree of neuromuscular blockade (intense or deep block) and that of posttetanic count between acceleromyography and electromyography.

Results: The authors analyzed 226 pairs of measurements. The percentage agreement indicating the same neuromuscular blockade status (intense or deep block) between acceleromyography and electromyography was 73%. Cohen's kappa coefficient value was 0.26. After excluding data with acceleromyography–posttetanic counts greater than 15, a total of 184 pairs of posttetanic counts were used to evaluate the agreement between the two monitoring methods. For acceleromyography–posttetanic count, 42 (23%) pairs had the same electromyography–posttetanic count, and 93 (50%) pairs had more than the electromyography–posttetanic count. The mean posttetanic count on electromyography was 38% (95% CI, 20 to 51%) lower than that on acceleromyography ($P = 0.0002$).

Conclusions: Acceleromyography frequently counted more twitches than electromyography in posttetanic count monitoring. Acceleromyography– and electromyography–posttetanic counts cannot be used interchangeably to assess the degree of neuromuscular blockade.

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Neuromuscular monitoring, particularly quantitative twitch monitoring, is recommended during anesthesia and recovery.[1] Although acceleromyography is easily and widely used clinically, it has some limitations in that the thumb must be unrestricted and free to move and the baseline train-of-four ratio is often greater than 1.0.[1–3] Electromyography has many advantages over mechanomyography or acceleromyography; free movement of the

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thumb is not required, no preload is needed, and it is less dependent on the maintenance of intraoperative normothermia.[1,4] Recently, several freestanding electromyography monitors have become commercially available.

Previous studies evaluated the agreement of train-of-four counts or ratios between acceleromyography and electromyography. Results showed that agreement of train-of-four counts between acceleromyography and electromyography was fair, and that acceleromyography underestimated the electromyography–train-of-four count.[5] However, another study showed that acceleromyography was less precise than electromyography and overestimated the electromyography–train-of-four ratio.[6]

Recently, robotic and laparoscopic surgeries have been increasing, and the burden of recovery from deep neuromuscular blockade has been reduced by the use of sugammadex.[7] Thus, the desire to maintain deep neuromuscular blockade during these surgeries is increasing; deep neuromuscular blockade creates a good surgical field, requires low carbon dioxide inflation pressure, and reduces postoperative pain.[8–10] Although the evidence for routine use of deep neuromuscular blockade for laparoscopic surgery is insufficient,[11] posttetanic count measurement is important for clinical situations requiring maintenance of deep neuromuscular blockade.

However, to our knowledge, the comparison of posttetanic counting by acceleromyography and electromyography has not been well studied. The objective of this study was to assess the agreement of posttetanic counts, including agreement of neuromuscular blockade status (intense block, posttetanic count equal to 0; or deep block, posttetanic count 1 or greater and train-of-four count equal to 0)[12] between acceleromyography and electromyography.

Materials and Methods

This study was conducted at Ewha Womans University Mokdong Hospital (Seoul, Republic of Korea) from October 12, 2020, to February 23, 2021. Thirty-six patients, aged 23 to 65 yr, American Society of Anesthesiologists Physical Status I or II, scheduled for various elective surgeries that require positioning for more than 90 min under general anesthesia in the supine position with both arms abducted, were enrolled. The Institutional Review Board of Ewha Womans University Mokdong Hospital (Institutional Review Board No. 2020-06-001-002, Seoul, Republic of Korea) approved the study protocol on August 13, 2020, and written informed consent was obtained from all the patients. This trial was registered in the Clinical Trial Registry of Korea (http://cris.nih.go.kr, KCT0005444, posted on October 6, 2020; principal investigator, Hee Jung Baik, M.D., Ph.D.) before enrolling the first participant. Patients were excluded if they had neuromuscular, neurologic, or renal disease or body mass index greater than 25 kg/m^2.[13]

For neuromuscular blockade monitoring, we used acceleromyography (Philips IntelliVue Neuro Muscular Transmission Module 865383, Philips Healthcare, The Netherlands) and electromyography (TwitchView Monitor, Blink Device Company, USA) monitors that stimulated the ulnar nerves to obtain a twitch response from the adductor pollicis muscle for acceleromyography and the first dorsal interosseus or adductor pollicis muscle for electromyography. According to the Good Clinical Research Practice guidelines for neuromuscular monitoring,[13] acceleromyography was performed using two electrodes (3M Red Dot electrode 2248-50, 3M Healthcare, USA) placed 3 to 6 cm apart over the ulnar nerve. An acceleration transducer was attached to the thumb and moved freely without preload. The second through the fourth fingers were attached to the arm board with surgical tape.[13–15] Electromyography electrode array was applied according to the manufacturers' guidelines, and we did not fix the patient's hand for electromyography monitoring. To reduce arm-to-arm variation, we attached both acceleromyography and electromyography electrodes to the dominant and nondominant arms in equal proportions using a computer-generated randomization table (Random Allocation Software, version 1.0; developed by M. Saghaei, Isfahan University of Medical Sciences, Iran).[16,17]

Effect-site concentration-target-controlled infusions of propofol and remifentanil were used for total intravenous anesthesia. After the patient was unconscious, acceleromyography and electromyography were calibrated using built-in calibration functions to determine the supramaximal current for nerve stimulation. Train-of-four stimulation at the supramaximal current was performed immediately before administration of 0.6 mg/kg IV rocuronium to the patients. Thereafter, train-of-four stimulation was given at 12-s intervals until tracheal intubation was performed when the train-of-four count was 0 to 3. If the patient's diaphragmatic or limb movement or cough was observed during or after tracheal intubation, or posttetanic count was not 0, an additional dose of rocuronium (0.3 mg/kg) was injected after intubation. When the train-of-four count was 0, the posttetanic count stimulus was performed at 6-min intervals, and the responses were recorded until the first twitch response in the train-of-four stimulus (T1) appeared. All patients were placed under an upper body forced air warming blanket (Bair Hugger, Augustine Medical Inc., USA), and the central temperatures were monitored in the nasopharynx and maintained greater than 36°C.

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Statistical Analysis

The normality of continuous data was tested using the Kolmogorov–Smirnov test and quantile–quantile plot evaluation. Data are expressed as number (percentage) for categorical data and mean ± SD for normally distributed data or median [interquartile range] for nonnormally distributed data. For paired measurements, comparisons of supramaximal stimuli current and the time for train-of-four count to reach 0 after rocuronium injection between acceleromyography and electromyography monitoring were analyzed using the Wilcoxon signed-rank test. Cohen's kappa statistic was used to assess the agreement of the neuromuscular blockade status (intense or deep block) between acceleromyography and electromyography monitoring. To evaluate the relationship between acceleromyography–posttetanic count *versus* electromyography–posttetanic count, a scatter plot was presented. The maximum number of stimuli for posttetanic count monitoring of acceleromyography used in this study was 20, and that of electromyography was 15. Therefore, to evaluate the agreement of posttetanic counts between acceleromyography and electromyography monitoring, we excluded data with acceleromyography–posttetanic counts greater than 15. Owing to the nature of the data, Poisson regression analysis was performed to establish the percentage limits. It considered both correlations between paired measurements and between multiple measurements in the same subject. If overdispersion was suspected, negative binomial Poisson regression analysis was performed. Statistical analyses were performed using SPSS software (SPSS for Windows, Version 22.0, IBM Corp., USA) and R statistical software version 3.6.2 (R Foundation for Statistical Computing, Austria). *P* value < 0.05 was considered statistically significant. PASS software (PASS 11, NCSS, LLC, USA)[18] was used to calculate the sample size of 142 measurements to achieve a power of 90% and an alpha of 0.05, with a dropout rate of 20% when the null hypothesis was "no agreement" and the expected kappa coefficient was 0.3.[19] This strategy was based on the results of a previous study comparing train-of-four agreement between acceleromyography and electromyography.[5] Since an average of four measurements per patient was expected to be possible, we enrolled 36 patients.

Results

Of the enrolled 36 patients, one patient was excluded from statistical analysis because of measurement failure (fig. 1). Patient characteristics are shown in table 1. No significant difference was observed in the amplitude of the supramaximal stimulus (mA; median [interquartile range]) between

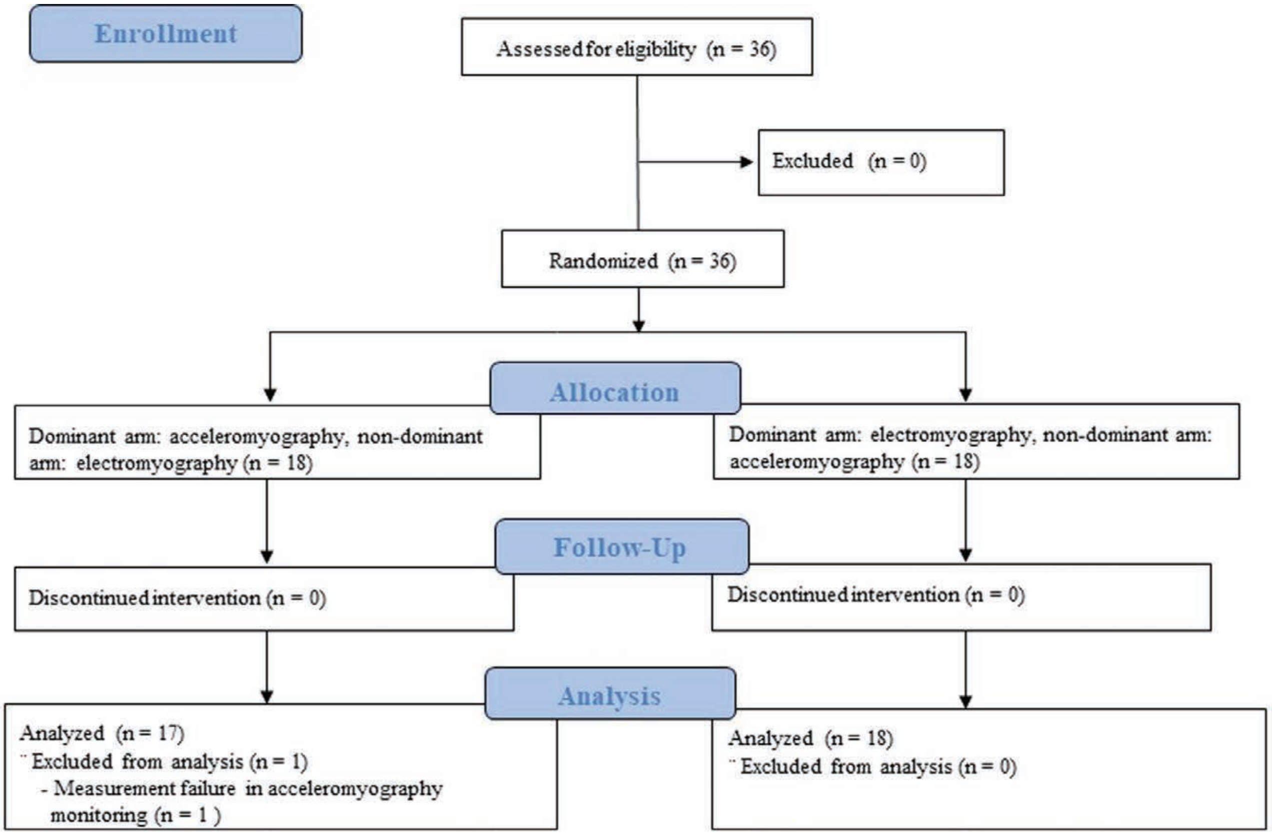

Fig. 1. Consolidated Standards of Reporting Trials flow diagram.

Table 1. Demographic Data

	Patients (n = 35)
Sex	
Men	19 (54%)
Women	16 (46%)
Age, yr	53 [47–62]
Height, cm	165.4 ± 7.8
Weight, kg	63.1 ± 9.3
Body mass index, kg/m^2	22.9 ± 2.1
ASA Physical Status	
I	15 (43%)
II	20 (57%)
Dominant arm	
Right	35 (100%)
Left	0
Study arm	
Dominant arm: acceleromyography, nondominant arm: electromyography	17 (49%)
Dominant arm: electromyography, nondominant arm: acceleromyography	18 (51%)

Data are number of patients (%), mean ± SD, or median [interquartile range]. ASA, American Society of Anesthesiologists.

acceleromyography (60 [50–60] mA) and electromyography (48 [48–54] mA; *P* = 0.518). The time from administration of rocuronium to the start of posttetanic count measurement when the train-of-four count reached 0 was not significantly different between acceleromyography (180 [120–320] s) and electromyography (150 [100–255] s; *P* = 0.248).

We analyzed 226 pairs of posttetanic count measurements. The percentage agreement indicating the same neuromuscular blockade status (intense or deep block) between acceleromyography and electromyography was 73%, and Cohen's kappa coefficient (95% CI) was 0.26 (0.12 to 0.40; table 2). The kappa coefficient showed positive value, thus indicating that the actual agreement for intense or deep block between acceleromyography and electromyography is greater than agreement by chance.

Figure 2 shows a scatter plot of acceleromyography–posttetanic count *versus* electromyography–posttetanic count. This shows that the range of electromyography–posttetanic count values measured to correspond to acceleromyography–posttetanic count is very wide. Forty-two out of 226 pairs were excluded for the comparison of posttetanic count between the two monitors because electromyography–posttetanic count had a maximum value of 15. For acceleromyography, out of 184 pairs, 42 (23%) acceleromyography–posttetanic counts were equal to electromyography–posttetanic counts, 93 (50%) were more than electromyography–posttetanic counts, and 49 (27%) were less than electromyography–posttetanic counts (fig. 3). The mean posttetanic count on electromyography was 38% (95% CI, 20 to 51%) lower than that on acceleromyography (table 3).

Discussion

The main findings of this study are as follows: (1) The percentage agreement indicating the same neuromuscular blockade status (intense or deep block) between acceleromyography and electromyography was 73%, and Cohen's kappa coefficient was 0.26, which indicated that the actual agreement for intense or deep block between acceleromyography and electromyography was greater than coincidence. (2) For posttetanic count, 23% and 50% of acceleromyography–posttetanic counts were equal to and greater than electromyography–posttetanic counts, respectively, which indicated that acceleromyography frequently counted more twitches than electromyography for posttetanic counts. (3) The mean posttetanic count on electromyography was 38% lower than that on acceleromyography.

Currently, the importance of objective neuromuscular monitoring during and after anesthesia is emphasized. Among the objective neuromuscular monitoring devices, mechanomyography is impractical for clinical use despite being the accepted standard for neuromuscular monitoring. Acceleromyography is the most widely used clinically, but it is not interchangeable with mechanomyography or electromyography.[5,6,20–22] The electromyography–train-of-four ratio obtained at the first dorsal interosseus muscle is reportedly equivalent to mechanomyography during the recovery phase.[2,4,23] Several studies have shown that acceleromyography–train-of-four counts and ratios are not interchangeable with electromyography.[5,6,22]

Table 2. Agreement of Intense Block or Deep Block between Acceleromyography and Electromyography

		Electromyography			
		Intense Block	Deep Block	Total	Cohen's Kappa Coefficient (95% CI)
Acceleromyography	Intense block	22 (10%)	16 (7%)	38	0.26 (0.12–0.46)
	Deep block	45 (20%)	143 (63%)	188	
	Total	67	159	226	

Data are number of measurements (%). Intense block, posttetanic count equal to 0; deep block: posttetanic count 1 or greater and train-of-four count equal to 0.

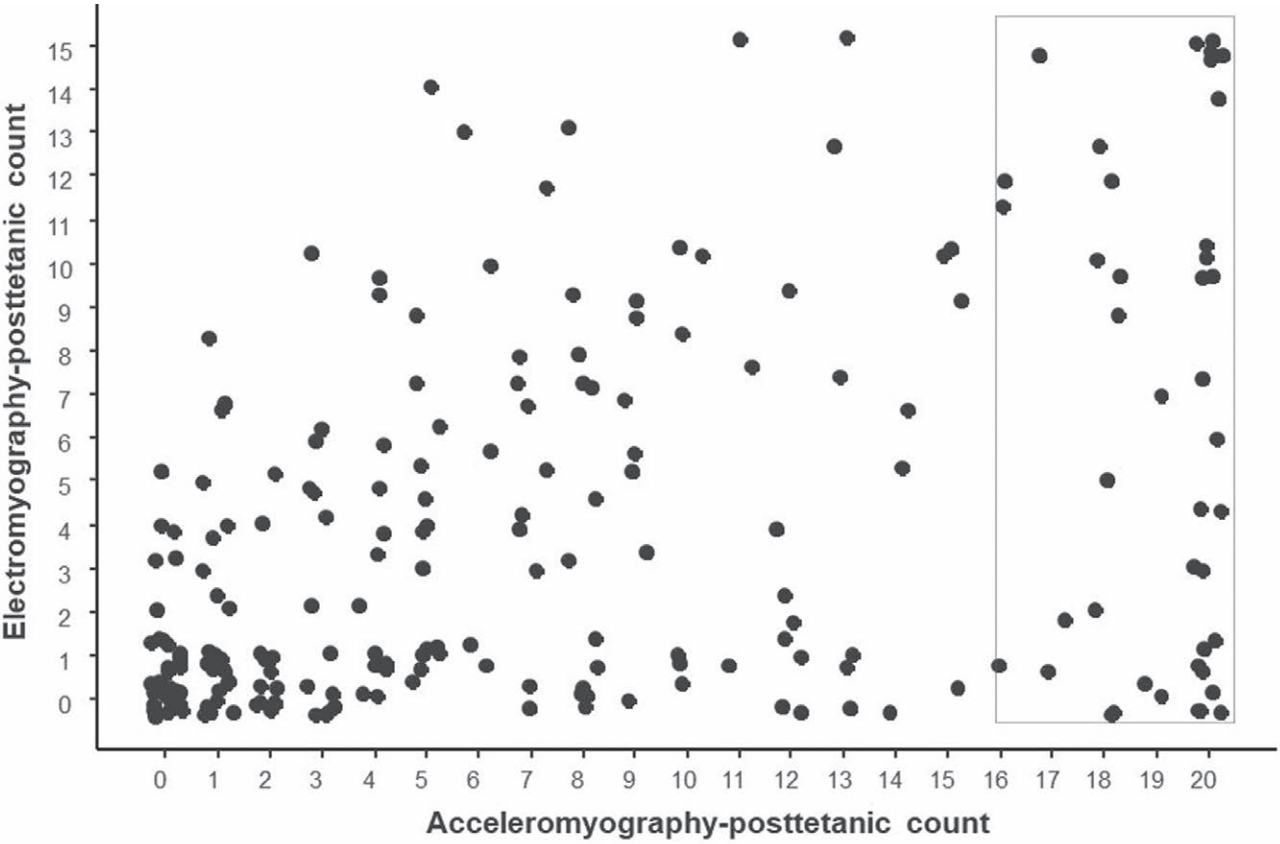

Fig. 2. Scatter plot of acceleromyography–posttetanic count *versus* electromyography–posttetanic count. Out of all 226 pairs, 42 (in the *rectangular box*) showed an acceleromyography–posttetanic count number of 16 or more.

The use of deep neuromuscular blockade during anesthesia in laparoscopic or robotic surgeries may have several advantages in terms of patient outcomes and physician surgical experience. Posttetanic count can be used to estimate the extent of intense to deep neuromuscular block and time to recovery.[24,25] Dhonneur *et al.* demonstrated that posttetanic count at the adductor pollicis was a better indicator of early diaphragmatic recovery than train-of-four at the corrugator supercilii, and a posttetanic count at the adductor pollicis of 5 or less corresponded to deep neuromuscular block of the diaphragm.[15] Fernando *et al.* also showed that the neuromuscular blockade of adductor pollicis should be intense (posttetanic count equal to 0) to ensure total diaphragmatic paralysis.[26] Therefore, posttetanic count monitoring is useful for achieving and maintaining deep neuromuscular blockade during these surgeries.

However, to date, the agreement of posttetanic count between acceleromyography and electromyography has not been well studied. This study aimed to verify the agreement between acceleromyography and electromyography for posttetanic count measurements to evaluate whether the two devices were clinically interchangeable determining the status of neuromuscular blockade (intense or deep block). Our results showed that the percentage agreement indicating the same neuromuscular block status (intense or deep block) between acceleromyography and electromyography was 73%, and that Cohen's kappa coefficient value was 0.26, which indicates greater agreement than coincidence. This is consistent with the results of a study by Bowdle *et al.* for train-of-four response, which showed that the value of Cohen's kappa coefficient between acceleromyography and electromyography was fair (kappa = 0.38).[5]

We also performed pairwise comparisons of the posttetanic count using acceleromyography and electromyography. Twenty-three percent of acceleromyography–posttetanic counts were equal to electromyography–posttetanic counts, and 50% were greater. This indicates that compared with electromyography, acceleromyography frequently counted more twitches for the posttetanic count. Previous studies also have shown clinically significant differences between electromyography and acceleromyography with respect to train-of-four count[5] and train-of-four ratio.[6,22] These differences are attributed to several factors, including differences in monitoring devices used, differences in the side of the monitored arm (ipsilateral or contralateral), whether examiners apply preload to the thumb and/or restrain

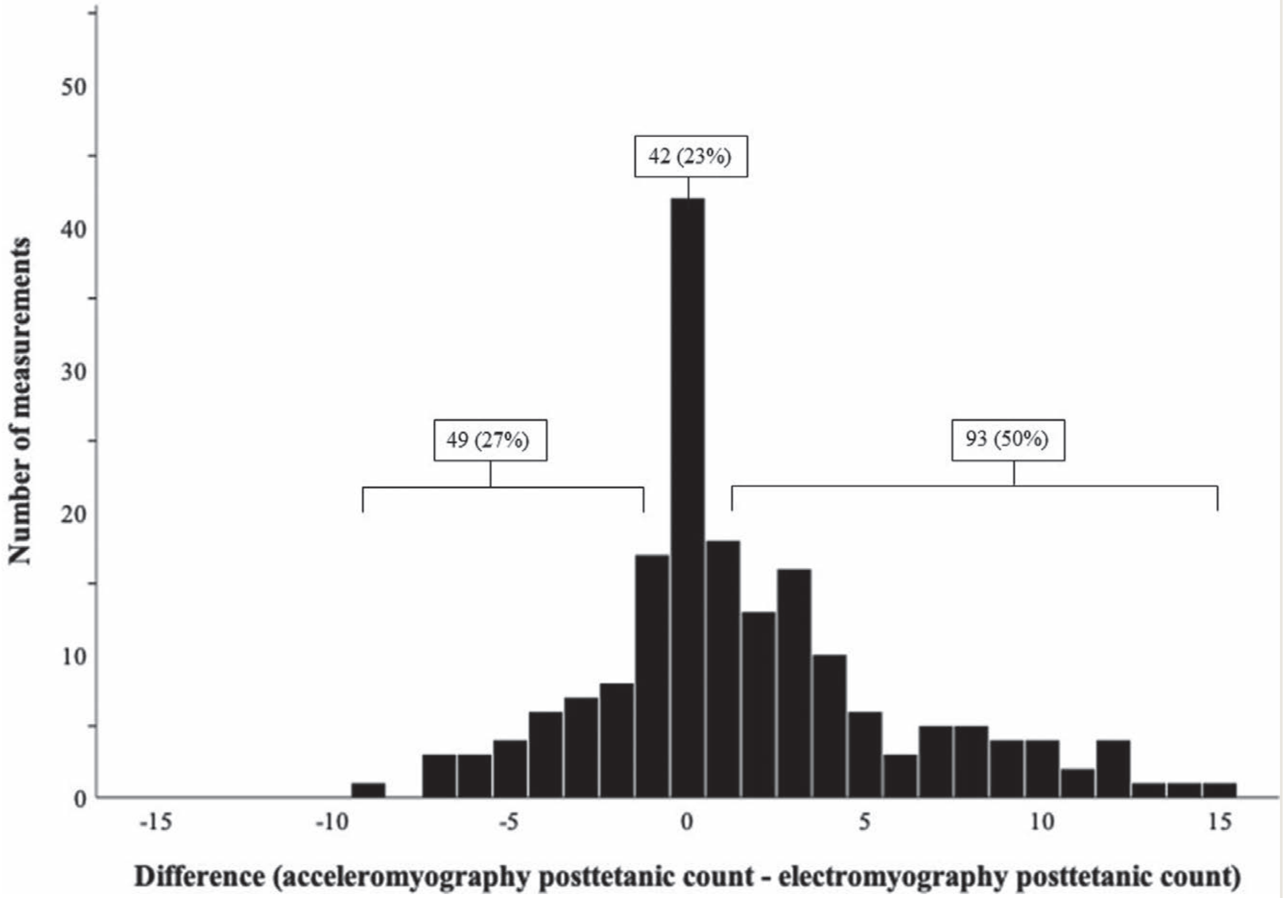

Fig. 3. Distribution of difference between acceleromyography–posttetanic count and electromyography–posttetanic count. For acceleromyography, 23% of acceleromyography–posttetanic counts were equal to electromyography–posttetanic counts, 50% were more than, and 27% were less than electromyography–posttetanic counts.

Table 3. Percentage Limits of Posttetanic Counts between Acceleromyography and Electromyography Estimated by the Poisson Model

	Estimated Ratio	Lower 95% CI	Upper 95% CI	*P* Value
Electromyography	0.62 [0.57–0.68]	0.49	0.80	0.0002
Acceleromyography	Reference			

Estimated ratio [interquartile range] and 95% CI were obtained from the negative binomial Poisson regression analysis.

finger movement during acceleromyography monitoring, and whether examiners normalize acceleromyography values. Among several electromyography twitch monitors, the TwitchView monitor has been validated to most closely resemble mechanomyographic assessment of the train-of-four ratio compared to acceleromyography (Stimpod, Xavant Technology, South Africa).[2] In addition, train-of-four counting by electromyography (TwitchView) or palpation were more similar to mechanomyography than acceleromyography (Stimpod).[5] Moreover, in comparison between electromyography monitors, the GE Healthcare electromyography monitor showed the greater train-of-four count and ratio than those measured by the TwitchView monitor.[27] However, the agreement of the TwitchView with mechanomyography for posttetanic count has not been well evaluated. In addition, the use of the Philips IntelliVue acceleromyography monitor in evaluating the twitch response has not been well studied for comparison to mechanomyography or electromyography. Our finding that the scatter in the posttetanic count data was very large (fig. 2) could be attributed to either of the two monitors. This concern can be addressed by further studies, in which the TwitchView electromyography– and the Philips IntelliVue acceleromyography–posttetanic counting are compared to mechanomyography and/or palpation. Although we may not be able to draw clear conclusions based on past studies and lack of studies, our finding that acceleromyography (Philips IntelliVue Neuro Muscular Transmission Module) counted the greater posttetanic count compared to electromyography using the TwitchView suggests that anesthesiologists may administer higher doses of muscle relaxants when monitoring neuromuscular function using acceleromyography than electromyography; therefore, this should be considered for the maintenance of deep neuromuscular blockade with posttetanic count monitoring during laparoscopic or robotic surgeries.

Considering the nature of the data shown in figure 2, Poisson regression analysis performed to establish percentage limits showed that the mean posttetanic count on electromyography was 38% lower than that on acceleromyography (table 3). This result seems to be related to the finding that the ratio belonging to the acceleromyography–deep block and the electromyography–intense block (20%) was approximately three times higher than that in the opposite case (7%) (table 2).

This study had several limitations. First, the acceleromyography and electromyography for posttetanic count were compared in the contralateral arms. Because the electromyography electrodes of the TwitchView monitor used in this study occupied a large area, they could not be attached to the arm on the same side as the acceleromyography electrodes. Considering that arm-to-arm variation is a possible source of variation when monitors are compared on opposite arms, we applied both acceleromyography and electromyography monitors to the dominant and nondominant arms in equal proportions. This may have reduced the differences due to arm-to-arm variations. However, Claudius *et al.* found that there was no mean bias between the arms.[16] Second, the patient's hand temperature was not monitored. However, we monitored and maintained the patient's nasopharyngeal temperature within the normal range (36.0 to 37.0°C) using a forced-air warming blanket. Third, the number of data pairs analyzed for the agreement of intense block or deep block and the agreement of posttetanic count between the two monitors were 226 and 184, respectively. These numbers may seem relatively small; however, they exceeded 142 measurements determined from the sample size calculation. Future studies with more measurements are required. Fourth, we did not compare acceleromyography and electromyography with mechanomyography or twitch response by manual palpation for posttetanic count monitoring. Therefore, we do not know which monitor is more accurate for posttetanic counts between acceleromyography and electromyography. Further studies are needed to clarify this point. Fifth, we simply compared acceleromyography with electromyography for posttetanic count and did not observe any relationship with clinical issues to surgical stimuli, including intra-abdominal pressure to secure an appropriate surgical field, peak airway pressure, patient outcome, and the surgeon's satisfaction during laparoscopic or robotic surgeries. Future research could investigate whether electromyography or acceleromyography is a more suitable device in these respects.

In conclusion, this observational study demonstrated that acceleromyography (Philips IntelliVue) frequently counted more twitches than electromyography (TwitchView) in posttetanic count monitoring, and the posttetanic counts measured using acceleromyography and electromyography are not interchangeable for assessing the degree of neuromuscular blockade.

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Competing Interests

The authors declare no competing interests.

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