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Evaluation of twitch responses obtained from abductor hallucis muscle as a monitor of neuromuscular blockade: comparison with the results from adductor pollicis muscle

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Abstract: The twitch responses evoked from the abductor hallucis muscle (AHM) and the adductor pollicis muscle (APM) were examined simultaneously in 20 anesthetized patients following a single bolus intravenous administration of 0.04 $mg \cdot kg^{-1}$ of vecuronium bromide. The mean onset time of vecuronium-induced depression of AHM twitch responses was significantly slower than that of APM twitch responses (4.9 ± 1.5 min *vs* 3.7 ± 1.2 min, mean ± SD, $P < 0.001$), and when the clinical duration times of vecuronium were compared, AHM twitch responses recovered more quickly than APM twitch responses (15.3 ± 4.1 min *vs* 19.6 ± 6.7 min, $P < 0.01$), although there was no statistically significant difference in the spontaneous recovery time between AHM and APM (9.8 ± 2.9 min *vs* 10.0 ± 3.6 min). It is concluded that the twitch responses of AHM may be a useful monitor of neuromuscular blockade in anesthetized patients in whom setting the blockade monitor on the patient's arms is difficult, although monitoring of twitch response of AHM is less sensitive than that of APM in case of vecuronium administration.

Key words: Abductor hallucis muscle, Adductor pollicis muscle, Monitoring of neuromuscular blockade, Vecuronium, Twitch response

Introduction

To monitor neuromuscular blockade during anesthesia, contractive responses of the adductor pollicis muscle (APM) elicited by ulnar nerve stimulation have been evaluated by means of either a force or acceleration transducer. Results obtained from both transducers have been confirmed as correlating well with each other [1]. However in cases of intracranial surgical procedures and/or patients in the lateral or prone position, some difficulties are encountered in setting up the monitoring system of neuromuscular blockade on an arm or hand. The present study was aimed to examine availability of monitoring the abductor hallucis muscle (AHM) elicited by tibial nerve stimulation, and to evaluate the difference between responses to vecuronium which were obtained concurrently from AHM and APM.

Patients and methods

Twenty patients who were scheduled to undergo tympanoplasty with ASA physical status 1 or 2 without evidence of neuromuscular diseases, were included in this study. Eight male and 12 female patients ranging in age from 15 to 67 years (42.2 ± 12.5 years, mean ± SD) were studied. Informed consent to undertake the study was obtained from all patients.

Premedication by intramuscular injection of 0.01 $mg \cdot kg^{-1}$ of atropine and 1 $mg \cdot kg^{-1}$ of pethidine was performed 1 h before surgery. After anesthesia had been induced with intravenous injection of 0.1–0.25 $mg \cdot kg^{-1}$ of droperidol, 6–10 $\mu g \cdot kg^{-1}$ of fentanyl and a sleeping dose of thiamylal, the patients were ventilated with 8 $l \cdot min^{-1}$ of oxygen via a semi-closed circuit using a mask.

The forearm on the opposite side to surgery and either lower leg were prepared for fixing individual acceleration transducers on the thumb and the great toe as shown in Fig. 1. Surface electrodes for electrical stimulation were applied to the tibial nerve just dorsal to the medial malleolus, and to the ulnar nerve just proximal to the wrist joint (Fig. 1). Supramaximal stimulation with square pulses 0.2 msec in duration was applied to both nerves at a frequency of 0.1 Hz, and the induced twitch responses were recorded continuously on a separate Myograph 2000 (Biometer I/S, Copenhagen, Denmark). After the control values were recorded, the patients were tracheally intubated with an intravenous injection of 1 $mg \cdot kg^{1}$ of succinylcholine, and anesthesia

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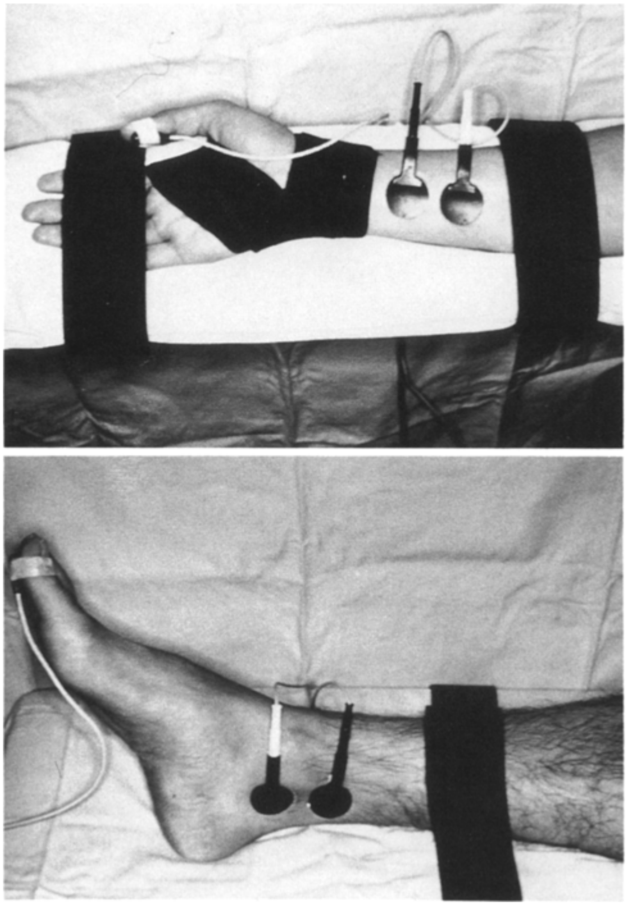

Fig. 1. Application of acceleration transducers and fixation of the palm (*above*) and the leg (*below*)

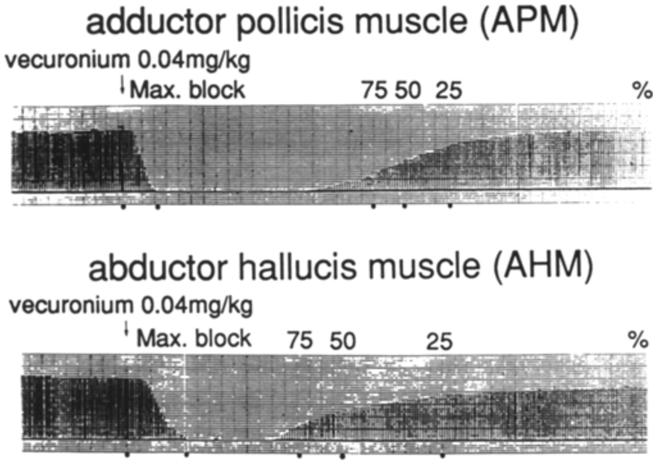

Fig. 2. A sample of simultaneous records of the twitch responses at the adductor pollicis muscle (*APM*) and abductor hallucis muscle (*AHM*), showing the differentiation between both records in onset time and time course during recovery

was maintained under controlled ventilation with 4 l·min^{-1} of nitrous oxide and 2 l·min^{-1} of oxygen to maintain Spo_2 of 99% and $Petco_2$ of 35–38 mmHg with additional fentanyl and thiamylal.

After the heights of the twitch responses had recovered to the levels prior to succinylcholine administration, 0.04 mg·kg^{-1} of vecuronium was given as a single intravenous bolus. The twitch responses were recorded continuously until complete recovery was achieved, as shown in Fig. 2.

The results obtained from the first administration of vecuronium in each case were evaluated to avoid the influence of different gradients in temperature between the test extremities. The records from the 20 cases were analyzed for the following variables: (1) maximal block (%)—percent inhibition from control at maximal depression of twitch height; (2) onset time (min)—the time from administration of vecuronium to complete maximal block of the twitch height; (3) clinical duration time (min)—the time from administration of vecuronium to recovery to 25% of control of the twitch height; and (4) spontaneous recovery time (min)—the time from 25% to 75% of control of twitch height during the recovery phase.

In addition, various inhibited twitch heights of AHM were compared with those of APM at the same periods during the onset and recovery phases in each block, and the correlation of both rates was analyzed from the simple linear regression which was obtained from all values in 20 patients.

The results are expressed as the mean values and standard deviations (mean ± SD). Statistical comparisons between the results obtained from both muscles were made by paired Wilcoxon test, and P values of less than 0.05 were considered to indicate statistical significance.

Results

The mean levels of the maximal blocks in both muscles were 99.5 ± 1.4% inhibition for APM and 98.9 ± 3.1% inhibition for AHM. No statistically significant difference was noted between these values (Table 1). Significant linear correlations between the inhibited twitch heights of both muscles were observed during the onset ($y = 0.58x + 52.15$, $r = 0.589$, $P < 0.01$, $n = 220$) and recovery phases ($y = 0.80x + 24.12$, $r = 0.668$, $P < 0.01$, $n = 220$) of the neuromuscular block (Figs. 3 and 4).

The mean onset time was significantly slower in AHM than in APM (4.9 ± 1.5 min *vs* 3.7 ± 1.2 min, $P < 0.001$) (Table 1), although a linear correlation was noted between both muscles as shown in Fig. 5 ($y = 1.0x + 1.22$, $r = 0.636$, $P < 0.01$, $n = 20$).

Table 1. Parameters obtained from both muscles

	Maximal block (%)	Onset time (min)	Clinical duration time (min)	Spontaneous recovery time (min)
Adductor pollicis muscle	99.5 ± 1.4	3.7 ± 1.2*	19.6 ± 6.7**	10.0 ± 3.6
Abductor hallucis muscle	98.9 ± 3.1	4.9 ± 1.5*	15.3 ± 4.1**	9.8 ± 2.9

Mean ± SD $n = 20$.
* $P < 0.001$, ** $P < 0.01$.

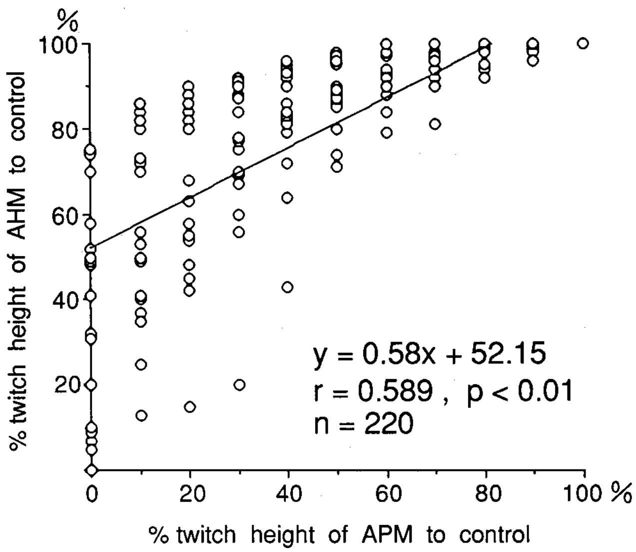

Fig. 3. Correlation between % twitch heights to control both responses from APM and AHM during progress of neuromuscular block. The values of blockade obtained from AHM are lower than those from APM

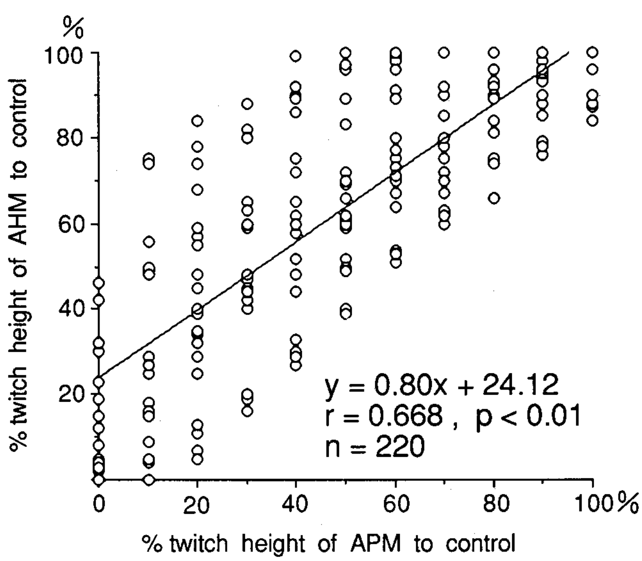

Fig. 4. Correlation between % twitch heights to control of both responses from APM and AHM during recovery of neuromuscular block. The values of blockade obtained from AHM are lower than those from APM

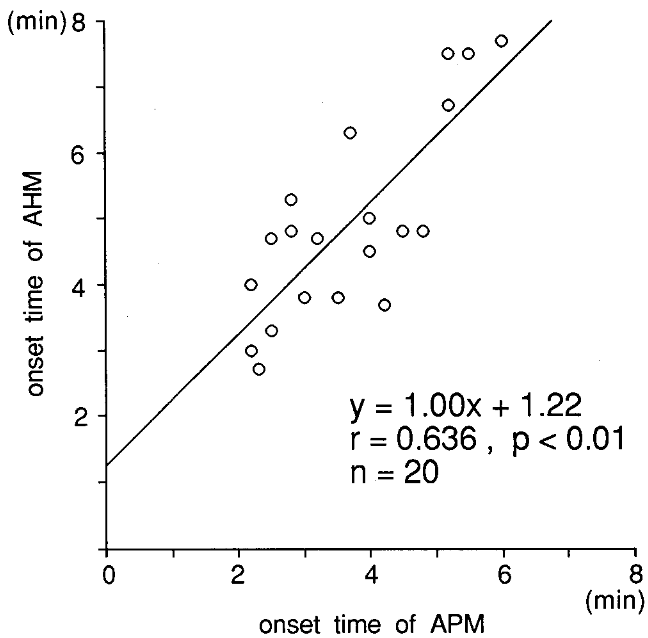

Fig. 5. Correlation between both onset times obtained from APM and AHM

The mean clinical duration time was significantly shorter in AHM than in APM (15.3 ± 4.1 min *vs* 19.6 ± 6.7 min, $P < 0.01$) (Table 1). The onset time and the recovery times to 25%, 50%, and 75% of control during recovery periods from each inhibited twitch height are listed in Table 2. Recovery times in AHM at the three levels were shorter than that in APM (25% and 50% recovery, $P < 0.01$; 75% recovery, $P < 0.05$, respectively) except for the time to complete maximal block ($P < 0.001$). An example of serial records of the twitch heights from a patient is shown in Fig. 2. The recovery pattern on the record from AHM revealed a rather rapid recovery during the initial stage when compared to that from APM. The spontaneous recovery time from 25% to 75% recovery of the twitch heights, however, did not differ significantly between the records from the two muscles (9.8 ± 2.9 min in AHM, and 10.0 ± 3.6 min in APM) (Table 1).

Table 2. Duration from IV administration of vecuronium to maximal block and to various recovery periods of twitch height

	Maximal block (min)	25% recovery (min)	50% recovery (min)	75% recovery (min)
Adductor pollicis muscle	3.7 ± 1.2***	19.6 ± 6.7**	23.6 ± 7.5**	29.6 ± 8.7*
Abductor hallucis muscle	4.9 ± 1.5***	15.3 ± 4.1**	19.2 ± 4.6**	25.2 ± 6.3*

Mean ± SD $n = 20$.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Discussion

When the twitch responses from AHM and APM were estimated concurrently during vecuronium neuromuscular blockade in these 20 patients, the results demonstrated that the mean onset time obtained from AHM was slower and the mean clinical duration time was shorter than those obtained from APM, although the levels of inhibition of their twitch heights were essentially correlated.

Concerning the etiology of these differences between the results from the two muscles, pharmacokinetic factors affecting the drug in reaching the neuromuscular junctions after its administration should be considered. However, the circulation time of blood flow to arms and legs could not be considered the reason for the observed difference. Based on our results, the difference of 1.2 min between the two mean onset times (3.7 ± 1.2 *vs* 4.9 ± 1.5 min, Table 1) in the present study could not be regarded as the main cause of the difference. Further, the differences between the clinical duration times from the two muscles may be difficult to explain from the standpoint of the pharmacokinetics [2]. It is strongly suspected, therefore, that these differences in sensitivity to vecuronium between the two muscles examined in this study could reflect differences in the compositions of muscle fibers in each.

Generally, muscle fibers are categorized into three subtypes based on their construction and contractive velocity [3]; namely, fast twitch fibers (type IIA, red muscle; and type IIB, white muscle) and slow twitch fibers (type I, red muscle). All muscles are composed of varying proportions of these subtypes, and the relative ratios govern the contractive velocity of the muscle. Muscles characterized with fast contraction include a higher percentage of type II fibers, and muscles characterized by slow contractions are predominantly type I fibers. It has been suggested that fast twitch fibers tend to be more sensitive to depolarizing relaxants, and slow twitch fibers to be sensitive to non-depolarizing relaxants [4–6]. Johnson et al. [7] found that APM contained 80.4% of type I and 19.6% of type II fibers. Although they did not provide detailed information on the proportions for AHM, it is probable that AHM contains a greater proportion of type II fibers than does APM, and that this difference in composition may give rise to the observed decreased sensitivity to vecuronium when compared to that of APM.

Muscle temperature has a tendency to decrease with time during anesthesia, and this decrease may influence the degree of blockade [8,9]. In the present study under these conditions, the results from both muscles were obtained at the first administration of vecuronium to avoid influencing the neuromuscular blockade from different temperature gradients in the arm and leg muscles. Under these conditions, average levels of more than 90% neuromuscular block were obtained from both muscles with 0.04 $mg \cdot kg^{-1}$ of vecuronium, which corresponds to approximately 1.4·ED_{90} in Japanese patients [10].

It is concluded from the present results that the twitch responses of AHM may be a useful monitor for neuromuscular blockade in anesthetized patients in whom it is difficult to place an arm monitor, even though the twitch responses of AHM are less sensitive than those of APM in the case of vecuronium administration.

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