

Comparison of the Neuromuscular Blocking Effect of Atracurium and Vecuronium on the Adductor Pollicis and the Geniohyoid Muscle in Humans

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Background: Residual paralysis of suprahyoid muscles may occur when the adductor pollicis response has completely recovered after the administration of a neuromuscular blocking agent. The response of the geniohyoid muscle to intubating doses of muscle relaxants is evaluated and compared to that of adductor pollicis.

Methods: Sixteen patients undergoing elective surgery under general anesthesia were given 5–7 mg·kg⁻¹ thiopental and 2 µg·kg⁻¹ fentanyl intravenously for induction of anesthesia. Eight (half) patients then received 0.5 mg·kg⁻¹ atracurium, and the other eight received 0.1 mg·kg⁻¹ vecuronium. The evoked response (twitch height, TH) of the adductor pollicis was monitored by measuring the integrated electromyographic response (AP EMG) on one limb and the mechanical response, using a force transducer (AP force), on the other. The activity of geniohyoid muscle (GH EMG) was measured using submental percutaneous electrodes. The following variables were measured: maximal TH depression; onset time for neuromuscular blockade to 50%, 90%, and maximal TH depression (OT50, OT90, and OTmax); times between administration of neuromuscular blocking agent and TH recovery to 10%, 25%, 50%, 75%, and 90% of control; and time for return of train-of-four ratio to return to 0.7.

Results: The principal findings were (1) OTmax was significantly ($P < 0.01$) shorter for geniohyoid than for adductor pollicis after either atracurium or vecuronium (OTmax was 216, 256, and 175 s for AP force, AP EMG, and GH EMG, with atracurium and 181, 199, and 144 s with vecuronium, respectively), and (2) the evoked EMG of geniohyoid recovered at the same speed as the EMG of adductor pollicis after an intubating dose of atracurium or vecuronium (recovery of TH to 75% of control at 50, 48, 42 min with AP force, AP EMG, and GH EMG with atracurium and 46, 45, and 42 min with vecuronium, respectively).

Conclusions: Once the adductor pollicis response has returned to normal values after a single intubating dose of atracurium or vecuronium, the risk of residual depression of the TH of the geniohyoid muscle, one of the principal muscles contributing to airway patency, appears unlikely. (Key words: Measurement techniques: electromyograph. Muscle, skeletal: adductor pollicis; geniohyoid. Neuromuscular relaxants: atracurium; vecuronium.)

PAVLIN *et al.*¹ suggested that, after paralysis with *d*-tubocurarine, muscles contributing to airway protection still may be paralyzed while the inspiratory muscles return to normal function. In the dog, it has been shown that the evoked response of the geniohyoid muscle is depressed after vecuronium to a greater intensity and duration as compared to that of the diaphragm.² Therefore, it is possible that residual paralysis of glossal muscles remains when the adductor pollicis response has completely recovered after the administration of a neuromuscular blocking agent. Residual paralysis of the geniohyoid muscle during recovery from anesthesia may have deleterious consequences on the patency of upper airways. The contraction of the geniohyoid muscle is important to counteract the collapsing pressure created by the inspiratory thoracic pump.^{3,4} Monitoring of the adductor pollicis muscle may not guarantee detection of any residual paralysis of glossal muscles contributing to the patency of upper airways and to pharyngeal clearance.

In the current study, the response of the geniohyoid muscle to an intubating dose of atracurium or vecuronium is evaluated by electromyography and compared to that of the adductor pollicis in anesthetized patients.

Materials and Methods

Ethical Committee approval and informed patient consent were obtained. Sixteen patients, aged between 39 and 65 yr, undergoing elective orthopedic surgery

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Table 1. Onset Time (s) of Neuromuscular Blockade to 50%, 90%, and to Maximal Twitch Height Depression (OT_{50} , OT_{90} , OT_{max}) after Atracurium $0.5 \text{ mg} \cdot \text{kg}^{-1}$ and Vecuronium $0.1 \text{ mg} \cdot \text{kg}^{-1}$ Evaluated by the Electromyographic (EMG) or the Mechanical Response of the Adductor Pollicis and Geniohyoid Muscle in Anesthetized Patients

Muscle Relaxant	Muscle Response	OT_{50} (s)	OT_{90} (s)	OT_{max} (s)
Atracurium $0.5 \text{ mg} \cdot \text{kg}^{-1}$	Adductor pollicis force	90 ± 29	175 ± 35	216 ± 64
	Adductor pollicis EMG	105 ± 39	170 ± 50	$256 \pm 65^*$
	Geniohyoid EMG	75 ± 50	130 ± 62	$175 \pm 81^\dagger$
Vecuronium $0.1 \text{ mg} \cdot \text{kg}^{-1}$	Adductor pollicis force	85 ± 22	165 ± 24	181 ± 36
	Adductor pollicis EMG	105 ± 52	165 ± 37	$199 \pm 47^*$
	Geniohyoid EMG	70 ± 51	120 ± 47	$144 \pm 35^\dagger$

Values are mean \pm SD.

* $P < 0.05$ versus adductor pollicis force.

† $P < 0.01$ versus adductor pollicis EMG.

under general anesthesia were included in the study. All patients remained in the supine position during anesthesia and surgery. No premedication was given. Anesthesia was induced with $5\text{--}7 \text{ mg} \cdot \text{kg}^{-1}$ thiopental and $2 \mu\text{g} \cdot \text{kg}^{-1}$ fentanyl and maintained with 60% N_2O in oxygen and repeated doses of $2 \mu\text{g} \cdot \text{kg}^{-1}$ fentanyl. A single dose of $0.5 \text{ mg} \cdot \text{kg}^{-1}$ atracurium was administered intravenously over 20 s to eight patients, and $0.1 \text{ mg} \cdot \text{kg}^{-1}$ vecuronium by intravenous bolus was given to the other eight patients. After tracheal intubation, controlled ventilation was adjusted to maintain the end-tidal carbon dioxide at 4.5%, and anesthesia was maintained with 70% N_2O in oxygen with boluses of fentanyl ($1 \mu\text{g}/\text{kg}$) as necessary. To prevent hypothermia, all patients were covered with a warming blanket (Bair Hugger, Augustine Medical, La Praye, Switzerland), and tympanic temperature monitored and maintained greater than 36°C .

Measurements

The evoked response (measured as the twitch height, TH) of the adductor pollicis was monitored by measuring simultaneously, every 10 s, the electromyographic response (EMG) after supramaximal single twitch ulnar nerve stimulation on one limb, and the mechanical response after supramaximal train-of-four stimulation on the contralateral limb. Ulnar nerves were stimulated at the wrist using skin-surface electrodes. The mechanical TH of the thumb was measured using a force transducer (Entran, Les Clayes Sous Bois, France) with a preload of 200–250 g. The EMG of the adductor pollicis was recorded using a surface bipolar electrode of 5 mm interelectrode distance positioned on the thenar eminence.

The EMG of the geniohyoid muscle was recorded using a pair of 36-G Teflon-insulated platinum wire electrodes using the technique of Wiegand *et al.*⁴ At the

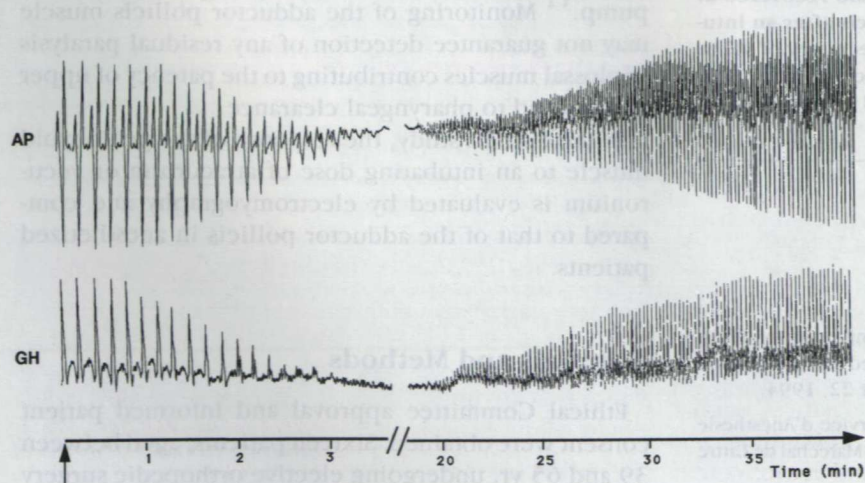


Fig. 1. Recording of the EMG-evoked response of the adductor pollicis and the geniohyoid after the administration of a single dose of $0.1 \text{ mg} \cdot \text{kg}^{-1}$ vecuronium.

ATRACURIUM VERSUS VECURONIUM

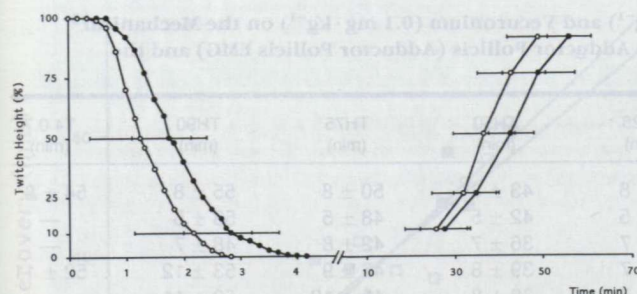


Fig. 2. Evolution of the twitch height (mean \pm SD) expressed as a percentage of control value obtained by electromyography of the geniohyoid (open circles) and the adductor pollicis (filled circles) in eight anesthetized patients after a bolus intravenous dose of $0.5 \text{ mg} \cdot \text{kg}^{-1}$ atracurium.

tip of the electrodes, the last 2 mm of insulating Teflon were removed. The two electrodes were inserted percutaneously through two 22-G intramuscular needles, 2.5 cm deep to the skin surface, midway between the mentum and the hyoid bone, and 0.5 and 1.5 cm lateral to the submental midline. The ipsilateral hypoglossal nerve was stimulated simultaneously every 20 s using subcutaneous wire electrodes placed at the level of the angle of the mandible. The electromyographic TH of the adductor pollicis and the geniohyoid muscle were evaluated by integration of the EMG during a window gate of 10 ms and with a latency time of 2 ms after nerve stimulation (Viking 2, Nicolet, Trappes, France). The following variables were obtained from the monitoring of TH: maximal depression of the TH; time between the end of injection of the muscle relaxant and the achievement of 50%, 90%, and maximum TH depression (OT50, OT90, and OTmax); and times between muscle relaxant administration and recovery of the TH height to 10%, 25%, 50%, 75%, and 90% of control (TH10, TH25, TH50, TH75, and TH90). The time for return of the train-of-four ratio of the mechanical response to 70% (T4 0.7) also was measured.

Data are presented as mean \pm SD. Comparisons between the mechanical and electromyographic response of the thumb and between the two muscles studied were performed using Wilcoxon's test. Linear correlations between the measured parameters were studied using the method of least squares analysis.

Results

Atracurium and vecuronium caused a 100% depression of the TH of the adductor pollicis and geniohyoid

muscle. No significant differences in onset time of the thumb TH were observed, whether it was assessed by electromyography or with a force transducer, and also whether atracurium or vecuronium were administered (table 1). A recording of the evoked EMG response of the adductor pollicis and the geniohyoid is shown in figure 1. OT50 and OT90 were not significantly different between the geniohyoid and the adductor pollicis. OTmax (assessed by EMG) was significantly ($P < 0.01$) shorter for geniohyoid than for adductor pollicis muscle after either atracurium or vecuronium.

During the recovery from neuromuscular blockade, muscle-evoked response could be monitored simultaneously on the adductor pollicis and the geniohyoid muscle (figs. 2 and 3), and there was no significant difference between the parameters measured by EMG in the two muscles (table 2). The thumb-twitch values measured with EMG or with a force transducer were also indistinguishable during recovery from paralysis induced by atracurium or vecuronium. The TH90 of geniohyoid muscle was 48 ± 7 and 49 ± 13 min after atracurium and vecuronium, respectively. This did not differ from the TH90 of the EMG of adductor pollicis, which was 53 ± 5 and 50 ± 11 min for atracurium and vecuronium, respectively. The return of the T4 0.7 of the thumb was achieved at 54 ± 8 and 52 ± 11 min after atracurium and vecuronium, respectively. No significant correlation was observed between the TH75 and the TH90 of the adductor pollicis and geniohyoid after atracurium (fig. 4). A significant linear correlation was observed between the TH75 and the TH90 of the adductor pollicis and geniohyoid after vecuronium (fig. 5). The longest delay recorded between the recovery of the EMG of adductor pollicis and geniohyoid following atracurium was 8 min in one patient, TH90

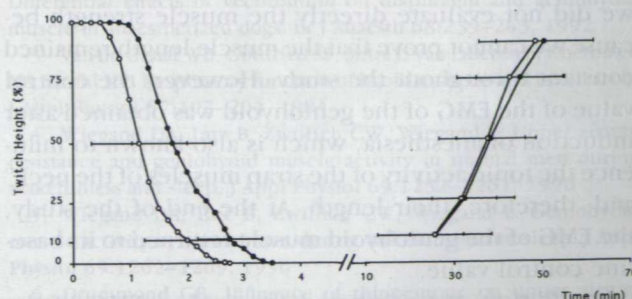


Fig. 3. Evolution of the twitch height (mean \pm SD) expressed as a percentage of control value obtained by electromyography of the geniohyoid (open circles) and the adductor pollicis (filled circles) in eight anesthetized patients after a bolus intravenous dose of $0.1 \text{ mg} \cdot \text{kg}^{-1}$ vecuronium.

Table 2. Neuromuscular Blocking Effect of Atracurium ($0.5 \text{ mg} \cdot \text{kg}^{-1}$) and Vecuronium ($0.1 \text{ mg} \cdot \text{kg}^{-1}$) on the Mechanical (Adductor Pollicis Force) and Electromyographic Response of the Adductor Pollicis (Adductor Pollicis EMG) and the Geniohyoid Muscle (Geniohyoid EMG)

Muscle Relaxant	Evoked Response	TH10 (min)	TH25 (min)	TH50 (min)	TH75 (min)	TH90 (min)	T4 0.7 (min)
Atracurium	Adductor pollicis force	30 ± 7	37 ± 8	43 ± 8	50 ± 8	55 ± 8	54 ± 8
	Adductor pollicis EMG	27 ± 5	34 ± 5	42 ± 5	48 ± 5	53 ± 5	—
	Geniohyoid EMG	25 ± 7	31 ± 7	36 ± 7	42 ± 8	48 ± 7	—
Vecuronium	Adductor pollicis force	28 ± 5	34 ± 7	39 ± 8	46 ± 9	53 ± 12	52 ± 11
	Adductor pollicis EMG	25 ± 6	32 ± 7	38 ± 8	45 ± 10	50 ± 11	—
	Geniohyoid EMG	25 ± 14	31 ± 12	37 ± 12	42 ± 13	49 ± 13	—

Values are mean \pm SD.

The time intervals between administration of atracurium or vecuronium and recovery of the evoked response to 10, 25, 50, 75, and 90% of control values are defined as TH10, TH25, TH50, TH75, TH90, and return of train-of-four ratio of the mechanical response to the adductor pollicis to 70% as T4 0.7.

of the geniohyoid recovering after adductor pollicis (fig. 4).

Discussion

The principal findings of the present study are (1) the onset time of neuromuscular blocking effect is shorter at the geniohyoid than at the adductor pollicis, and (2) the evoked EMG of the geniohyoid muscle follows the same speed of recovery as the EMG of the adductor pollicis after an intubating dose of atracurium or vecuronium.

We chose to record the evoked response of the geniohyoid muscle rather than that of genioglossus muscle because the contraction of this muscle contributes to the pharyngeal patency by displacing the hyoid bone anteriorly. In comparison, the genioglossus muscle, which has multiple actions in addition to dilatating the upper airway, contributes to articulation of speech and swallowing.⁵ By measuring the EMG-evoked response, we did not evaluate directly the muscle strength because we cannot prove that the muscle length remained constant throughout the study. However, the control value of the EMG of the geniohyoid was obtained after induction of anesthesia, which is also known to influence the tonic activity of the strap muscles of the neck⁶ and, therefore, their length. At the end of the study, the EMG of the geniohyoid muscle returned to its baseline control value.

In addition, we compared the evoked EMG of the geniohyoid to that of the adductor pollicis using the same mode of nerve stimulation. Therefore, we assume that the evoked response of these two muscles can be compared.

During the onset of paralysis, we observed that the geniohyoid was paralyzed more rapidly than the thumb (comparing EMGs). Although this finding may not be relevant clinically, it can be explained by the shorter transit time from the venous site of injection to the muscle arterioles⁷ for geniohyoid than for adductor pollicis muscle. As geniohyoid muscle is more proximal and possibly better perfused than the adductor pollicis muscle, this is probably the main reason for the variation in onset time.

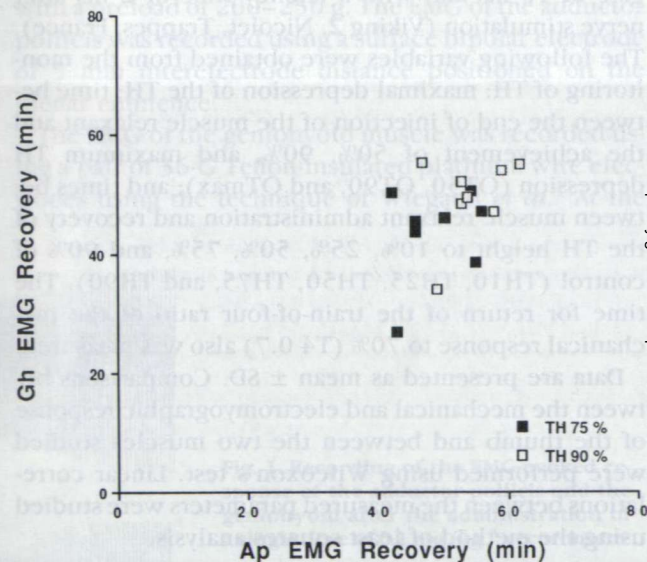


Fig. 4. Relationship between the recovery time of the electromyographic response of adductor pollicis (Ap EMG) and geniohyoid muscle (Gh EMG) at 75% (TH75) and 90% (TH90) of twitch height control values in eight patients receiving atracurium ($0.5 \text{ mg} \cdot \text{kg}^{-1}$). Each symbol represents an individual patient. Filled symbols and open symbols correspond to TH75 and TH90 values, respectively.

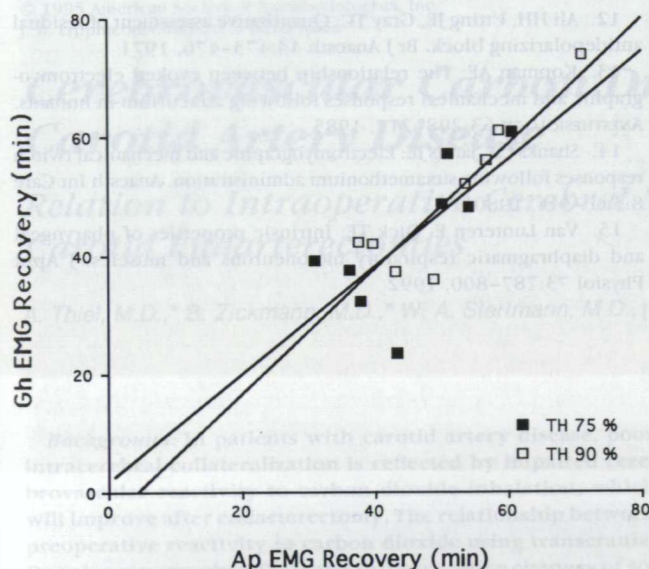


Fig. 5. Relationship between the recovery time of the electromyographic response of adductor pollicis (Ap EMG) and geniohyoid muscle (Gh EMG) at 75% (TH75) and 90% (TH90) of twitch height control values in eight patients receiving vecuronium ($0.1 \text{ mg} \cdot \text{kg}^{-1}$). Each symbol represents an individual patient. Filled symbols and open symbols correspond to TH75 and to TH90 values, respectively. A linear relationship was observed between ApEMG and GhEMG corresponding to TH75 (GhEMG (min) = $1.12 \text{ ApEMG (min)} - 2.8 \text{ min}$, $r = 0.73$, $P < 0.05$) and to TH90 (GhEMG (min) = $0.93 \text{ ApEMG (min)} + 4.5 \text{ min}$, $r = 0.90$, $P < 0.01$).

During recovery from neuromuscular blockade, the geniohyoid muscle recovered from paralysis at the same rate as the adductor pollicis. Although there was some interindividual variation in response to muscle relaxant, we did not observe great individual variability in the response between the adductor pollicis and geniohyoid muscle. As seen in the figures 2 and 3, when the adductor pollicis EMG had recovered to 90% of the control value, in most of the patients, the geniohyoid also had returned to 90% within the same period. In one patient receiving atracurium, the recovery of the TH90 of the geniohyoid was delayed by 8 min as compared to that of the adductor pollicis muscle. Some variability could be due to a change in local muscle temperature,⁸ and because adductor pollicis is situated more peripherally than the geniohyoid muscle, this muscle could be more hypothermic, especially during recovery from neuromuscular blockade. To eliminate this methodologic aspect, hypothermia was prevented throughout the study. Glossal muscle activity during swallowing was shown to be decreased by subparalyzing doses of muscle relaxants^{9,10} suggesting that glossal

muscles are more sensitive to muscle relaxants than peripheral muscles. The apparent discrepancies between these previous results^{9,10} and those of the current study may be explained by the difference in the assessment of the muscle response. Glossal muscle activity during swallowing is elicited by a centrally driven tetanic input. During recovery from neuromuscular blockade, it is known that tetanic fade occurs at a lower occupancy ratio than single twitch depression.¹¹ Therefore, glossal muscle activity during swallowing may be depressed by a lower dose of muscle relaxant than that necessary to diminish the TH of the geniohyoid.

The most widely used quantitative assessment of the adductor pollicis muscle is to record the mechanical response using a force transducer.¹² In the current study, the responses obtained by EMG or by mechanography were superimposable except for onset time. This finding confirms results from previous studies about the validity of EMG monitoring.^{13,14}

In summary, there is no residual depression of the TH of the geniohyoid muscle when the TH of the adductor pollicis muscle has returned to normal after a single dose of atracurium or vecuronium. The extrapolation of the current results to other skeletal muscles contributing to upper airway patency, such as the genioglossus muscle, remains speculative. However, these muscles receive the same innervation and are similar in their fiber composition¹⁵ and activity during respiratory movements.⁴

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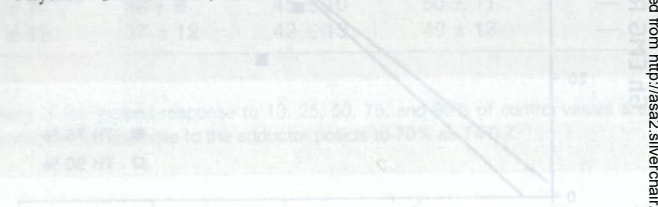


Figure 1. Relationship between the recovery time of the adductor pollicis muscle (T50) and the time to 90% recovery (T90). The data points are shown as open circles. The line represents the linear regression of the data. The equation of the line is $T_{90} = 1.19 T_{50}$. The correlation coefficient is $r = 0.99$, and the p -value is $p < 0.01$.

During recovery from neuromuscular blockade, the adductor pollicis muscle recovered from paralysis at the same rate as the adductor pollicis. Although there was some individual variation in response to muscle relaxants, we did not observe great individual variability in the response between the adductor pollicis and the geniohyoid muscle. As seen in the figures 2 and 3, when the adductor pollicis EMG had recovered to 90% of the control value, in most of the patients, the geniohyoid had returned to 90% within the same period. In the pattern receiving atracurium, the recovery of the T90 of the geniohyoid was delayed by 8 min as compared to that of the adductor pollicis muscle. Some variability could be due to a change in local muscle temperature, and because adductor pollicis is situated more peripherally than the geniohyoid muscle, this muscle could be more hypothermic, especially during recovery from neuromuscular blockade. To eliminate this possibility, we added to our study a patient who had received a priming dose of atracurium and was paralyzed with a bolus of 1.5 mg/kg. The patient received a bolus of 1.5 mg/kg of atracurium, and the adductor pollicis EMG had recovered to 90% of the control value. The geniohyoid had returned to 90% of the control value within the same period. In the pattern receiving vecuronium, the recovery of the T90 of the geniohyoid was delayed by 10 min as compared to that of the adductor pollicis muscle. Some variability could be due to a change in local muscle temperature, and because adductor pollicis is situated more peripherally than the geniohyoid muscle, this muscle could be more hypothermic, especially during recovery from neuromuscular blockade. To eliminate this possibility, we added to our study a patient who had received a priming dose of vecuronium and was paralyzed with a bolus of 0.1 mg/kg. The patient received a bolus of 0.1 mg/kg of vecuronium, and the adductor pollicis EMG had recovered to 90% of the control value. The geniohyoid had returned to 90% of the control value within the same period.