

## Jaw Relaxation after a Halothane/Succinylcholine Sequence in Children

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**Background:** Lack of complete jaw relaxation after a halothane-succinylcholine sequence has been described in the literature. To date, however, most existing studies are retrospective, and lack agreement on the magnitude and incidence of this phenomenon. This prospective study examined the incidence and degree of incomplete jaw relaxation in 500 children who were given intravenous succinylcholine during halothane anesthesia.

**Methods:** Five hundred consecutive unmedicated children received a minimum dose of 2 mg/kg intravenous succinylcholine after induction of anesthesia with halothane. The degree of jaw relaxation was assessed 45-60 s later by the same observer using a standardized clinical scale. The degree of relaxation was correlated with the type of surgical procedure, and the presence and intensity of fasciculations.

**Results:** Complete relaxation (mouth opened easily and fully) occurred in 95.4% of study patients. *Incomplete relaxation* (firm manual separation required to open the mouth fully) was seen in 4.4% of the patients. One child (0.2%) had *masseter muscle rigidity* (mouth could not be fully opened but intubation possible). There were no incidents of *trismus* (teeth clamped shut and intubation *via* direct visualization impossible). The incidence of *incomplete relaxation* and *masseter muscle rigidity* did not correlate with the presence or degree of fasciculations

or the type of surgical procedure. There were no clinical signs of a hypermetabolic state or myoglobinuria in any patient.

**Conclusions:** *Incomplete jaw relaxation* after a halothane-succinylcholine sequence is not uncommon in children, and is considered a normal response. (Key words: Anesthetics, volatile: halothane. Complications: masseter muscle spasm. Neuromuscular relaxants: succinylcholine.)

SEVERAL groups of investigators have described lack of complete jaw relaxation in children who were anesthetized with halothane and paralyzed with succinylcholine.<sup>1-6</sup> This phenomenon has variously been called "incomplete jaw relaxation," "masseter muscle rigidity" (MMR), "masseter spasm," or "trismus."‡ To date, however, there has not been a clear, consistent clinical definition of the above terms, an agreed upon scale to grade the response, or a way to establish any correlation between the lack of jaw relaxation and susceptibility to malignant hyperthermia (MH). Moreover, all of the reports involving large numbers of patients consist of retrospective examinations of anesthetic records that were completed by different anesthesiologists using their own criteria. This has resulted in confusion concerning the real incidence, significance and recommendations for anesthetic management when the administration of succinylcholine is followed by incomplete jaw relaxation in children.<sup>7-10</sup>

This paper presents the results of a prospective clinical study in which the same anesthesiologist used a standardized clinical grading scale to evaluate the response of the jaw muscles when succinylcholine is administered to children who are anesthetized with halothane.

### Materials and Methods

The following protocol has been used by one of the authors (RSH) for more than 20 yr, and was not modified for the purpose of this study. Five hundred consecutive children less than 12 yr of age were prospectively evaluated. Inclusion criteria included all ASA

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‡ In this paper, terms used by previous authors to describe the degree of incomplete jaw relaxation are indicated by quotation marks. When the definitions shown in table 1 are used, the terms are printed in italics.

**Table 1. Jaw Relaxation after Halothane/Succinylcholine Sequence**

Score	Relaxation	Definition
1	<i>Complete</i>	Mouth fully opens with head extension or pushing on chin
2	<i>Incomplete</i>	Mouth fully opens with firm manual separation of teeth
3	<i>Masseter muscle rigidity</i>	Mouth cannot be fully opened
4	<i>Trismus</i>	Intubation possible Teeth clamped shut Cannot intubate

physical status 1, 2, or 3 children requiring tracheal intubation for elective surgical procedures for which no further neuromuscular blockade was required. Patients with longstanding cerebral palsy were included, but children with a recognized myopathy or a recent neurologic injury were excluded. All patients had normal appearing airways on physical examination. No preoperative medications were used. Anesthesia was induced by the inhalation of nitrous oxide (60–70%) and oxygen, followed by halothane 1–4% as tolerated. When the depth of anesthesia was judged adequate, an intravenous cannula was inserted in a hand vein, and succinylcholine (Quelcin, Abbott Laboratories, North Chicago, IL) 2 mg/kg combined with atropine 0.02 mg/kg were immediately administered. Defasciculating doses of nondepolarizing muscle relaxants were not used in any of these patients. The volume of the succinylcholine-atropine mixture was rounded up to the nearest 0.5 ml and flushed with normal saline to ensure that a minimal dose of 2 mg/kg succinylcholine was delivered by bolus to each patient. The presence and degree of fasciculations were noted and graded as minimal if they were observed in one or two limbs with minimal movement, or generalized if vigorous sustained twitching of all muscles was observed. Laryngoscopy was attempted 45–60 s after succinylcholine administration, and jaw relaxation assessed by the same investigator (RSH) in all patients. A standardized clinical scale was used to assess jaw relaxation during laryngoscopy. The scale divided the spectrum of jaw relaxation into four clinical grades which are easy to distinguish clinically without the need for any instrumentation (table 1). Abdominal wall and upper extremity relaxation were also observed at the same time. No attempt was made to correlate the degree of

**Table 2. Relaxation Versus Surgical Procedure**

Procedure	Relaxation Score		Total
	1	≥2	
ENT	299 (97.1)	9 (2.9)	308 (100)
Ophth	88 (95.7)	4 (4.3)	92 (100)
GS/GU	31 (93.9)	2 (6.1)	33 (100)
Dental	17 (81.0)	4 (19.0)	21 (100)
Others	42 (91.3)	4 (8.7)	46 (100)
Total	477	23	500

Values in parentheses are percentages.

$P = 0.90$  (ophth vs. all others).

ENT = ear, nose, and throat; Ophth = ophthalmology; GS = general surgery; GU = genito-urinary.

jaw relaxation with the loss of twitch response of the hand muscles. All patients were monitored as per current ASA standards, including end-tidal carbon dioxide measurement after tracheal intubation. Axillary or esophageal temperature was also recorded. Anesthesia was continued with halothane and nitrous oxide unless a modification in the technique was clinically indicated. The degree of jaw relaxation was scored and recorded for all patients. The relaxation scores were correlated with the type of surgical procedure and with the presence and severity of fasciculations by chi-squared analysis.

## Results

Five hundred consecutive patients who met the inclusion criteria are presented. The mean ( $\pm$  SD) age of these children was  $4.4 \pm 2.4$  yr (range 0.25–12) and weight  $18.7 \pm 8.2$  kg (range 4–60). The type of surgical procedures performed is shown in table 2. The mean dose of succinylcholine ( $\pm$  SD) was  $2.3 \pm 0.5$  mg/kg (range 2.1–3.3) (table 3). The presence and severity of any observed fasciculations are shown in table 4. There was no increased muscle tone in the

**Table 3. Dose of Succinylcholine Versus Relaxation Score**

Relaxation Score	n (%)	Dose of Succinylcholine (mg/kg)
1	477 (95.4)	$2.3 \pm 0.5$
2	22 (4.4)	$2.2 \pm 0.3$
3	1 (0.2)	3.0
4	0	—

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Table 4. Relaxation Versus Fasciculations

Fasciculations	Relaxation	
	Complete (Score 1) (n = 477)	Incomplete (Score $\geq$ 2) (n = 23)
None	349 (73.2)	15 (65.2)
Minimal	109 (22.8)	65 (26.1)
Generalized	19 (4.0)	2 (8.7)

Values in parentheses are percentages.

Chi-square analysis (2) = 2.28;  $P = 0.32$ .

abdomen or extremities in any patient. *Complete relaxation* (score 1) was achieved in 95.4% of the study patients. The incidence of *incomplete relaxation* (score 2), *MMR* (score 3), and *trismus* (score 4) in this series was 4.4, 0.2, and 0% respectively (table 3). The incidence of all forms of incomplete jaw relaxation was not higher in children undergoing strabismus surgery (n = 92) versus all others (table 2). There was no association between the presence or degree of fasciculations and jaw relaxation (table 4). All cases, except the one child who had *MMR* (a 1-yr-old child undergoing epispadias repair), were continued under halothane anesthesia. No patient developed any signs of a hypermetabolic state as indicated by temperature or end-tidal carbon dioxide changes. All patients manifested an increase in heart rate after the administration of the succinylcholine-atropine mixture. No bradycardia or other dysrhythmia was observed. There was no clinical evidence of myoglobinuria in any case.

Incidentally, two patients manifested a prolonged response to the paralyzing effect of succinylcholine and were found to have abnormal pseudocholinesterase enzyme variants. Both had complete jaw relaxation after succinylcholine administration.

## Discussion

Succinylcholine was introduced into clinical practice in 1952 as a short acting muscle relaxant that until recently was considered the agent of choice to facilitate tracheal intubation in patients of all ages.<sup>11</sup> Reports of generalized muscle rigidity after succinylcholine administration started to appear in the literature about a decade later, and this phenomenon has been frequently linked with the syndrome of MH.<sup>12,13</sup> In 1970 Barlow and Isaacs,<sup>14</sup> and later, Donlon *et al.*<sup>4</sup> made a specific association between isolated rigidity of the mandibular

muscles (which was called "masseter spasm") after the administration of succinylcholine and MH. The definition, incidence and significance of this phenomenon, however, remained illusive.

Schwartz *et al.*<sup>1</sup> in 1984 published the results of a retrospective review of the anesthetic records of 6,500 patients in Boston, and reported a 1% incidence of "masseter spasm" in children who were anesthetized with halothane followed by intravenous succinylcholine. The diagnosis of "masseter spasm" in Schwartz's report was established "if the attending anesthesiologist found it extremely difficult, if not impossible, to open the patient's mouth after induction of anesthesia." A dose of succinylcholine of at least 1 mg/kg given intravenously was considered necessary to insure muscle relaxation. A similar incidence of "masseter spasm" (1.02%) was later reported in another retrospective study by Carroll from Pittsburgh.<sup>5</sup> The incidence was 2.8% in strabismus patients compared with 0.72% in patients without strabismus, a fourfold difference. This difference was not present in our patients. Carroll's definition of "masseter spasm" was "jaw tightness interfering with intubation that occurred despite an adequate dose of succinylcholine." Although the dose of succinylcholine was not reported in the original paper, it was later stated in a letter to the editor<sup>6</sup> to be 1.17 mg/kg (average), and that no patient received more than 1.6 mg/kg. The diagnosis of "masseter spasm" in each instance was the clinical judgment of the individual anesthesiologist.

More recently, Littleford *et al.*,<sup>10</sup> again in a retrospective review of approximately 42,000 anesthetics in Winnipeg, Canada, reported an overall incidence of "masseter muscle spasm (MMS)" of 0.3% of inhalation anesthetics during which succinylcholine was given. The definition of "MMS" used in this study was "if an obvious increase in the resistance to mouth-opening occurred, creating a transient impediment to tracheal intubation, despite the administration of what was considered to be an adequate dose of intravenous succinylcholine." Although some children in Littleford *et al.*'s report experienced intraoperative arrhythmias, increased serum creatine kinase levels, hypercapnia, or metabolic acidosis, the authors reported no long-term morbidity and no mortality.

The retrospective nature of these reports, however, is a serious flaw; retrospective differentiation between a normal and abnormal response is difficult at best. Still, they generated controversy and debate among anesthesiologists. Some clinicians who anesthetized thousands

of children every year rarely ever saw "masseter spasm,"<sup>15</sup> and those who did have not seen anywhere near the 1% incidence of "masseter spasm" after halothane-succinylcholine that has been reported. Furthermore, several investigators have reported that the results of contracture testing show MH susceptibility to be present in more than 50% of patients who had an episode of "masseter spasm."<sup>7,16</sup> These views were difficult to reconcile; either the susceptibility to MH is much greater in the general population than is generally believed, or the diagnosis of "masseter spasm" was incorrectly made or was made in normal patients.

In trying to address the latter question, Van Der Spek *et al.*<sup>2</sup> measured the resistance to mouth opening in 24 normal children who received intravenous succinylcholine (1, 1.5, or 2 mg/kg) while deeply anesthetized with halothane. They found a significant reduction in mouth opening and a significant increase in jaw stiffness immediately after limb relaxation in all patients. They concluded that succinylcholine, somewhat paradoxically, routinely increased rather than decreased jaw muscle tone when compared with nondepolarizing relaxants, and that an increase in jaw stiffness and a reduction in mouth opening without other signs and symptoms may be a normal pharmacologic response to succinylcholine given during deep halothane anesthesia. Although this study prospectively qualified the response of jaw muscles to succinylcholine, it did not examine a large enough sample to report the frequency and degree of incomplete relaxation.

Leary and Ellis<sup>3</sup> later confirmed the myotonic response of the masseter muscles to succinylcholine in healthy adults. Furthermore, they observed that the peak increase in muscle tone occurred about 30 s after the administration of succinylcholine, the same time that fasciculations were no longer visible. The magnitude, timing of the onset, as well as the duration of the increase in jaw tone showed a significant negative correlation with the dose of succinylcholine (*i.e.*, the higher the dose the less the magnitude and duration of increased jaw tone).

The use of a standardized scale to prospectively assess mandibular relaxation in a large number of patients is the main difference between our study and others. Using a single observer increases the internal consistency of the scale. This was not a blinded study, however, and it is possible that observational bias may have existed or that others may not find the same results. Nevertheless, it is very possible that the lack of complete relaxation described as "masseter spasm" by Schwartz

*et al.*<sup>1</sup> and Carroll<sup>5</sup> would have been classified as the mild form of *incomplete relaxation* (score 2) that we described. Our incidence of *MMR* (score 3) is similar to that reported as "masseter muscle spasm" by Littleford *et al.*<sup>10</sup>

Other variables that can influence the response of the jaw muscles to succinylcholine and thus cause difficulties in the interpretation of the results of previous studies include the depth of anesthesia, the dose of succinylcholine, and the timing of attempted laryngoscopy. In Van Der Spek *et al.*'s<sup>2</sup> study, the patients were deeply anesthetized with halothane before the administration of succinylcholine. This situation is not usually seen in clinical practice when succinylcholine or other muscle relaxants are used to facilitate tracheal intubation. The combination of deep halothane anesthesia and succinylcholine may have been responsible for the high frequency of clinically apparent increased jaw tone described in this study.

Children are known to require a larger (milligram per kilogram) dose of succinylcholine for intubation than adults. Meakin observed that children require at least 2 mg/kg and infants 3–4 mg/kg of succinylcholine to produce clinical effects comparable to those obtained in adults with the usual 1-mg/kg dose.<sup>9</sup> Thus previous studies may have confused "MMR" with insufficient dose of succinylcholine. Also, as suggested by Leary and Ellis,<sup>3</sup> the onset time of the increased jaw tone after succinylcholine and its duration are longest in patients who receive the lowest doses of the drug. Thus, studies using small doses may be expected to report a greater incidence of increased tone when laryngoscopy is attempted after succinylcholine.

As previously mentioned, the timing of laryngoscopy after succinylcholine is also critically important. Waiting too long, or not waiting long enough after the administration of succinylcholine may lead to inadequate jaw muscle relaxation. The timing of laryngoscopy attempts were not uniform in previous studies. Ironically, the time corresponding to the cessation of fasciculations and maximum jaw tone is the time when laryngoscopy and intubation are usually attempted. Laryngoscopy immediately after fasciculations end may cause the normal increase in jaw tone to be confused with "masseter spasm." As mentioned by Leary and Ellis,<sup>3</sup> the best time for laryngoscopy may be 20–30 s after cessation of fasciculations. Therefore, apparent *complete relaxation* occurred in our patients with high frequency perhaps because the large dose of succinylcholine resulted in the shortest duration of increased

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tone and because of the timing of our attempts at laryngoscopy.

Although this study was not conducted to correlate the relation between the degree of incomplete jaw relaxation and MH susceptibility, it is appropriate to remind the readers that in the case of the one patient who developed *MMR* (score 3), it was considered prudent to continue the anesthetic without further use of halothane or any other known triggering agent. This patient did not develop MH as judged by increases in carbon dioxide production, temperature elevation, or other clinical criteria. Even though MH never occurred in 500 patients given halothane and succinylcholine, this does not mean that MH never occurs with this drug combination. Also, because the number of patients in whom complete muscular relaxation did not occur after succinylcholine in our series is small, we cannot draw our own conclusions about the correlation between *MMR* or *trismus* and MH. Based on previous reports, however, they must continue to be considered to be significant events and treated as harbingers of MH.<sup>8</sup>

Succinylcholine is not an ideal neuromuscular blocking agent and its use in elective surgery is certainly diminishing.<sup>17,18</sup> A recent Food and Drug Administration-mandated label change now states that the drug is contraindicated in children except in situations when emergency tracheal intubation or immediate securing of the airway are necessary.<sup>19</sup> Succinylcholine is still the drug of choice for the treatment of laryngospasm, rapid-sequence induction, and when the trachea is accidentally extubated and emergent relaxation is needed for reintubation. Thus the evaluation and management of incomplete jaw relaxation after succinylcholine will continue to pose clinical and intellectual challenges.

In conclusion, we report the first prospective study to use a standardized clinical grading scale to evaluate the incidence of incomplete jaw relaxation after halothane and succinylcholine in a large number of children. *Incomplete relaxation* (score 2) is not uncommon and should be considered a normal response. *MMR* or *trismus* (scores 3 and 4) are rare, and until proven otherwise, should continue to be treated as harbingers of MH.<sup>8</sup> The use of the above described clinical grading scale is recommended to simplify and standardize the

assessment of incomplete jaw relaxation after the administration of succinylcholine.

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