sheet-like substance observed on the tube used in the patient described above. This film-like material lining the tubes peeled and clumped with flexion of the tubes causing narrowing of the lumen.

Conversely, none of the tubes coated with the ointment revealed any formation of the material observed on the tubes above even after seven hours of exposure to the gas flows.

Discussion

Examination of the anode tube used in this case disclosed a transparent, sheet-like thin film adherent to the entire inner surface of the tube which obstructed the lumen of the tube approximately 12 to 13 cm from its tip. By qualitative analysis, the substance was found to be methylcellulose, a vehicle of lidocaine jelly; none of the chemical agents used for cleaning and sterilization of the tube was found. We hypothesized that lidocaine jelly, applied as a lubricant, might have spread over the inner surface of the anode endotracheal tube. Because of the flow of dry inspired anesthetic gases, a membranous thin layer was formed inside of the tube. Postsurgical examination of the inner wall of the tube showed a shiny, scaly coating with some peeling and clumping. We believe bending of the tube during postural changes caused this thin layer to form a plug-like condition. By exposing the endotracheal tubes coated with lidocaine jelly to nitrous oxide and oxygen, we confirmed that this sheet-like substance was from the jelly.

This report serves to emphasize that lidocaine jelly should not be used as a lubricant either on the endotracheal tube or stylet. Conversely, lidocaine ointment, whose basic vehicle is polyethylene and propylene glycol, appears not to produce these problems. No conclusive data are available on the effects of various lubricants on the tracheal mucosa.[2,3]

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Dose Response to Intramuscular Succinylcholine in Children

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Succinylcholine is used frequently to terminate laryngospasm or to facilitate endotracheal intubation in pediatric patients. In these situations, it is often administered intramuscularly if a patent intravenous line is not available. Although there are several studies[1–4] concerning the effect of intramuscularly administered succinylcholine, the recommended dose of succinylcholine for children ranges from 1.5–3.0 mg/kg.[5–9] This study was undertaken to evaluate the neuromuscular blocking effects of intramuscularly administered succinylcholine in children utilizing muscle tension measurements and a nerve stimulator.

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Methods

This study was approved by the Subcommittee on Human Studies of the Committee on Research of the Massachusetts General Hospital and informed consent was obtained.

Fifty ASA Class I children scheduled for elective surgical procedures were studied. The children ranged in age from one to ten years and weighed between 7.3 and 31.5 kg. None of the children had evidence of neuromuscular disease and none were on drugs known to affect neuromuscular transmission. Premedication consisted of 20–25 mg/kg methohexital administered rectally.[10] After the children were asleep, anesthesia was induced by face mask and maintained with 1 to 1.5 per cent inspired

TABLE 1. Dose Response to Intramuscular Succinylcholine

	Group I	Group II	Group III	Group IV	Group V
Dose (mg/kg)	2	3	3	4	4
Number of injections	1	2	1	2	1
Number of patients	8	10	9	9	14
Maximum twitch depression (per cent)	19–100	20–100	0–100	85–100	97–100
Time to maximum depression (min)*	4.0 ± 0.7	4.9 ± 0.8	5.6 ± 1.1	3.9 ± 0.5	3.3 ± 0.4
Time to recovery (min)*	14 ± 2.3	20.5 ± 2.5	20.3 ± 1.0	19.6 ± 1.7	23 ± 1.1

* Values are means ± SE.

halothane, 3 liters per minute of nitrous oxide, and 2 liters per minute of oxygen. Heart rate was monitored with a precordial stethoscope and an electrocardioscope. Blood pressure was measured by the Riva-Rocci method. Patients were allowed to breathe spontaneously until succinylcholine was administered. After the administration of the drug, ventilation was controlled.

An ulnar nerve was stimulated in the forearm with a Grass S44 stimulator through a Grass SIU5 at a frequency of 0.1 Hz with 0.2 ms square wave pulses of supramaximal voltage. Thumb twitch was recorded on a Grass 7D polygraph through a Grass FT-03 force displacement transducer.

Patients were assigned at random to one of five groups (table 1). All children were given a 2 per cent solution of succinylcholine intramuscularly. Children in Group I received 2 mg/kg, those in Group II and Group III received 3 mg/kg, and those in Groups IV and V received a total dose of 4 mg/kg. Children in Groups I, II, and IV received the entire dose of succinylcholine in one deltoid muscle, whereas those in Groups III and V received half of the total dose in one deltoid muscle followed immediately by injection of the remaining half dose into the other deltoid muscle.

The twitch response of the adductor of the thumb was recorded prior to the injection of the drug and followed from the time succinylcholine was administered until twitch height returned to control level. The maximum amount of twitch depression, the duration of time between the administration of the drug and the onset of maximum twitch depression, and the duration of time between the administration of the drug and the return of twitch height to control levels were all measured.

In eight patients who received a total dose of 4 mg/kg, the response to train-of-four stimulation at 2 Hz for 2 s was recorded when twitch height returned to 20 to 30 per cent of control. The height of the fourth twitch (T_4) to the height of the first twitch (T_1) in the same train was calculated.

Analysis of variance and the Student's unpaired t test were applied to the data where applicable. Data were considered significant when $P < 0.05$.

RESULTS

Table 2 illustrates the frequency distribution of maximum twitch depression after different doses of succinylcholine. Maximum twitch depression varied widely after the intramuscular administration of 2 mg/kg and 3 mg/kg succinylcholine as compared to after 4 mg/kg. No difference was found between the doses in the time from the administration of the drug to the time of max-

TABLE 2. Frequency of Maximum Twitch Depression in Children after Intramuscular Succinylcholine

Maximum Twitch Depression (Per cent)	2 mg/kg	3 mg/kg		4 mg/kg	
	Group I (1)*	Group II (1)	Group III (2)	Group IV (1)	Group V (2)
0–9			1		
10–19	1				
20–29	2	1			
30–39					
40–49					
50–59					
60–69			1		
70–79					
80–89		1		1	
90–99	2	3	1	1	2
100	3	5	6	7	12

* Number in parentheses indicates number of injection sites.

imum twitch depression (table 1). Although there was no significant difference in recovery time between patients who received 3 mg/kg and those who received 4 mg/kg, recovery was significantly shorter after 2 mg/kg ($P < 0.001$).

The number of simultaneous intramuscular injection sites of succinylcholine did not result in a clinically significant difference in the maximum twitch depression, time to maximum depression or time to recovery.

The response to train-of-four stimulation was recorded in eight children who received 4 mg/kg succinylcholine intramuscularly. In all of these children, train-of-four fade was seen. The mean train ratio was 0.67 ± 0.13 SE. No patient had a train ratio of less than 0.5.

In this study, there was no clinically significant change in blood pressure, heart rate, or the electrocardiogram after succinylcholine was administered, except in one patient who received 3 mg/kg. In this patient, there was a transient 10-s episode of sinus bradycardia where heart rate fell from 120 to 80 beats per minute at the onset of maximum twitch depression. This episode of bradycardia resolved spontaneously.

Discussion

The currently recommended dose of intramuscularly administered succinylcholine in children ranges from 1.5 to 3 mg/kg.[5–9] In the clinical situation where succinylcholine is likely to be administered intramuscularly, a patent intravenous line would probably not be available. Airway obstruction may be present due to laryngospasm and muscle relaxation may be crucial for airway management. Our data indicates that the recommended doses may be insufficient to insure the relaxation needed for airway control. A number of patients in our study demonstrated very little twitch depression after receiving 2 mg/kg and 3 mg/kg of intramuscular succinylcholine. However, after 4 mg/kg, more than 85 per cent depression of control twitch height was achieved. For this reason, if succinylcholine is to be given intramuscularly, we would choose a dose of at least 4 mg/kg in order to be more certain of obtaining adequate muscle relaxation.

The time to maximum depression raises some interesting considerations in the use of intramuscular succinylcholine to treat laryngospasm. In an already asphyxiated child, the 3 to 4 min required for maximum relaxation after 4 mg/kg argues against its use. Nevertheless, clinical experience with intramuscular succinylcholine in children has been that airway control after laryngospasm is achieved in less time than the time to maximum depression. This indicates that less than 100 per cent depression of twitch is sufficient for the anesthetist to perceive the effects of the drug and regain control of the airway.

In order to investigate the clinical impression held by some anesthesiologists that succinylcholine is more effective is administered into two as opposed to one intramuscular site, we compared the twitch response after injection of the entire dose into one deltoid muscle with the response obtained after injection of the dose into both deltoid muscles. We found that there was no advantage to administering the drug in two injection sites.

In addition to the deltoid muscle, the quadriceps femoris, pectoralis major, and the tongue have been used in children for succinylcholine administration.[4,11] Mazze and Dunbar[4] compared different routes of administration of succinylcholine in children anesthetized with halothane, nitrous oxide and oxygen. They found that although the onset and duration of apnea after intralingual succinylcholine (0.5 mg/lb) is intermediate between that produced after intravenous administration (0.5 mg/lb) and after intramuscular administration (1 mg/lb), administration of the drug into the tongue resulted in a 28 per cent incidence of arrhythmias. No arrhythmias were seen in children who received the drug in a deltoid or quadricep femoris muscle. This is consistent with our study where the only significant arrhythmia was a transient episode of sinus bradycardia following a single intramuscular injection of 3 mg/kg.

When we compared our data with the adult data of Walts and Dillon,[12] we found that complete suppression of twitch after intramuscular succinylcholine was present in only 19 of 23 children who received 4 mg/kg, but that all 15 adults who received this dose developed a complete inhibition of twitch. This supports the contention that children require more succinylcholine than adults to produce the same intensity of neuromuscular blockade.[13]

Train-of-four fade was consistently seen after 4 mg/kg of intramuscular succinylcholine. Calculation of the train-ratio (T_4/T_1) resulted in a value of greater than 0.5 in all eight patients which we studied. In contrast, DeCook and Goudsouzian[14] found that 21 of their 22 children who received a total dose of 4 mg/kg by means of a continuous intravenous infusion had a train-ratio of less than 0.5. Thus, although a nondepolarizing (Phase II) block developed in all our patients who received train-of-four stimulation, this block was not as great as after an equivalent dose of intravenous succinylcholine.

In conclusion, our study shows that 4 mg/kg succinylcholine administered intramuscularly to children anesthetized with halothane, nitrous oxide, and oxygen produced a high percentage of twitch depression more consistently than smaller doses. Maximum twitch depression after this dose occurred at 3.5 min and full recovery took 21 min.

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