intubation is likely to be difficult, and understand and be able to use the variety of instruments available. Ideally, an instrument will be useful for both the routine and difficult tracheal intubation. In this context, the new laryngoscope offers advantages over currently available models, combining attractive features of both straight and curved bladed laryngoscopes and the refraction that is possible when a prism is used.

The epiglottis is lifted directly. This avoids the situation where the hyoid bone cannot be displaced forward and the epiglottis continues to obstruct a view of the larynx. In addition, the back of the tongue is completely flattened out to give a direct line of vision. The low profile permits insertion into a smaller mouth opening. So far, the correct length blade has never failed to display the larynx. However, it can be expected to fail in patients in whom the mouth opening is very small (under 2.5 cm), or where there is severe limitation of head extension on neck (intubation angle under 95°).

This laryngoscope has a similar shape to the Siker laryngoscope profile (but is less bulky than that instrument). Both the new blade and the Siker blade can be used in routine laryngoscopy, but are especially indicated where prior clinical examination suggests that laryngoscopy could be difficult or impossible with presently available laryngoscopes. The only contraindication to this new laryngoscope is in patients at risk for vomiting in whom rapid sequence induction and tracheal intubation is indicated and whose trachea is considered to be easy to intubate with the Macintosh laryngoscope, because, in this situation, the Macintosh blade has been found to be marginally quicker to use. In contrast to the Siker blade, which has a C-shaped cross section, this new blade has an inverted L (Γ)-shaped cross section. Consequently, in the majority of laryngoscopies, a direct view of the larynx is obtained. The prism facility of the new laryngoscope, although rarely required, provides greater convenience than the mirror (and its inverted image) that is always required with the Siker. In addition, the use of a single angle and provision of three sizes allows closer fitting and less risk of failure to insert the instrument when restricted mouth opening or head extension reduce intra-oral space.

In contrast with the Macintosh blade, because there is no curve on the horizontal component of the angulated laryngoscope, impairment of the view is rarely a problem. The use of a single angle, rather than a continuous curve, requires less compression of the tongue where its anterior displacement is restricted by the mandible, hyoid bone, and palato-glossal arch. The "inverted L" cross section of the blade leaves room for easy manipulation of an ET tube or Magill forceps in the mouth.

The new laryngoscope provides improved tracheal intubation conditions, resulting in fewer delayed and failed tracheal intubations.

The author wishes to thank Messrs. Hector Holcombe, John Sutton, Alan Simpson, and Richard Kenny for assistance in making the prototype of this laryngoscope blade and prism, Drs. E. D. Loong and A. MacKillop for constructive comments on the manuscript, Mr. Bruce Devine for photographic work, Mr. Michael Stanton-Cook for the art work, and Mrs. Rae Small for typing the manuscript.

REFERENCES


Neuromuscular Function Monitoring Comparing the Flexor Hallucis Brevis and Adductor Pollicis Muscles

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To monitor the response to muscle relaxants, the adductor pollicis muscle response to ulnar nerve stimulation is commonly observed or recorded. Occasionally, because of inaccessibility, the hand muscles are difficult to monitor in the operating room. The orbicularis oculi and flexor hallucis brevis muscles have been described as alternative sites for neuromuscular function monitoring. Previous studies, however, have demonstrated
that the evoked response of the orbicularis oculi muscle does not correlate well with that of the adductor pollicis muscle. The purpose of our study was to compare the response of the flexor hallucis brevis muscle to stimulation of the posterior tibial nerve with that of the adductor pollicis muscle to stimulation of the ulnar nerve.

MATERIALS AND METHODS

We studied ten adult ASA I or II patients with a mean age of 38 yr ± 5.1 SD (range 22–68 yr) undergoing elective surgical procedures. Approval of the Human Subjects Protection Committee at our institution and informed consent were obtained. No patient had a known neuromuscular disorder. All patients received midazolam 0.03–0.06 mg/kg iv in the preoperative room. Anesthesia was induced with fentanyl 1–2 μg/kg and thiopental 5 mg/kg iv. Vecuronium 0.1 mg/kg iv was administered to facilitate endotracheal intubation, and anesthesia was maintained with 70% nitrous oxide in oxygen and isoflurane (0.75–1.25% inspired concentration). Clinical relaxation was maintained with additional doses of vecuronium and, at the conclusion of the procedure, neuromuscular blockade was antagonized with edrophonium 1 mg/kg iv administered with atropine 15 μg/kg.

Neuromuscular function was monitored using two Puritan-Bennett Datex® NMT 221 Neuromuscular Transmission Monitors. One monitor measured thumb adduction by stimulating the ulnar nerve and recording the response of the adductor pollicis muscle. The other monitored large toe plantar flexion by stimulating the posterior tibial nerve and recording the response of the flexor hallucis brevis muscle (fig. 1). Standard EKG electrodes were used for attachment of both stimulating and recording leads.

After anesthesia was induced and before vecuronium was administered, the control EMG response of each muscle was recorded. Supramaximal stimulation was achieved using the nerve stimulator incorporated into the Datex monitor (pulse width 0.1 ms, constant current, 0–70 mA range). Train of four (TOF) stimulation, with a frequency of 2 Hz, was given every 20 s for the duration of the anesthetic. Single twitch depression (height of first twitch in a train/control twitch) and TOF fade ratio were continuously recorded by each monitor. Data used to compare the responses of both muscles included the times from administration of muscle relaxant to the reappearance of initial twitch (T1), 20% twitch recovery (T1 = 20%), and first appearance of train of four (TOF). Final twitch height following reversal was used as the control twitch height for calculating T1 = 20%. Reversal was defined as T4/T1 > 75%. The time from administration of vecuronium to 100% twitch depression and time from edrophonium administration to reversal were measured in both mus-

![FIG. 1. Schematic diagram of the foot illustrating EMG lead placements. Stimulation of the posterior tibial nerve by electrodes at the infero-lateral aspect of the medial malleolus results in plantar flexion of the large toe.](image)

icles. Twitch height had returned to greater than 20% of control in both the hand and foot in every patient at the time of reversal administration.

Analysis of the data obtained was performed using the paired t test, assuming P < 0.05 to be significant.

RESULTS

The results are given in table 1. There was no significant difference in recovery times between the hand and the foot. Initial twitch returned in the hand an average of 1.6 min (±2.75 SD) before the foot. T1 in the hand became equal to 20% of control an average of 0.4 min (±7.84 SD) sooner than the foot. TOF returned on average 0.7 min (±8.15 SD) faster in the foot than the hand. None of these differences were statistically significant. In addition, there was no statistical difference between the hand and foot with respect to times to 100% twitch depression after the initial dose of vecuronium (3.3 min in the hand and 3.6 min in the foot). After edrophonium administration, the T4/T1 ratio became greater than 75% within 2 min in every patient in both the hand and the foot.

DISCUSSION

Monitoring of neuromuscular blockade during anesthesia is an essential component of anesthetic management. Most commonly, the response of the adductor pollicis to stimulation of the ulnar nerve is used to assess neuromuscular function. However, in the operating room, the hand is occasionally inaccessible. In such cases, the foot may be the most convenient site for neuromuscular function monitoring.

Stiffel et al.2 and Caffrey et al.3 compared ulnar nerve and facial nerve train of four stimulation, and demonstrated that there is a more rapid recovery of TOF re-
### TABLE 1. Times (min) to Recovery of One Twitch, First Twitch Equal to 20% of Control, and Train of Four in the Hand and Foot

<table>
<thead>
<tr>
<th>Patient</th>
<th>Recovery of T1*</th>
<th>Recovery T1 = 20%†</th>
<th>First Appearance of TOF‡</th>
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<tbody>
<tr>
<td></td>
<td>Hand</td>
<td>Foot</td>
<td>Hand</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>44</td>
<td>49</td>
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</tr>
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<td>10</td>
<td>34</td>
<td>34</td>
<td>42</td>
</tr>
<tr>
<td>Mean</td>
<td>31.8</td>
<td>33.4</td>
<td>43.6</td>
</tr>
</tbody>
</table>

* Standard deviation of the differences = ±2.75.
† Standard deviation of the differences = ±7.84.
‡ Standard deviation of the differences = ±8.15.

Response in the face. Monitoring at the orbicularis oculi muscles may, therefore, result in a relative underestimation of neuromuscular blockade and subsequent difficulty assessing reversibility of the relaxant.

Pansard et al.4 have recently shown that the effects of atracurium and succinylcholine on the diaphragm and adductor pollicis are different. Recovery of the diaphragm occurred earlier than recovery of the adductor pollicis. They hypothesized that this difference was due to either physiologic and ultrastructural differences between the muscles or differences in regional blood flow. Although the ultrastructure of the flexor hallucis brevis muscle has not been described, it seems reasonable to assume that this muscle type may be similar to that of the adductor pollicis.

Although some variability was found between hand and foot recovery, the direction of the difference was not consistent. Our results showed that, in five patients, the hand recovered to T1 = 20% sooner than the foot; while, in the other five patients, the foot recovered sooner than the hand. Katz5 found that, following administration of pancuronium, when T1 was greater than 20% of control in the hand, antagonism of neuromuscular blockade could be readily achieved within 3–15 min with neostigmine administration. In seven of the ten patients, the difference in time to recovery to T1 = 20% between the hand and foot was less than 5 min. In two of the three other patients, the foot recovered 9 and 14 min slower than the hand, giving a relative overestimation of neuromuscular blockade, but, still, a reliable assessment of reversibility. In one patient, recovery of the foot to T1 = 20% preceded that of the hand by 15 min. However, the patient's initial recovery of T1 in the hand and foot occurred within 1 min of each other, and, at T1 = 20% in the foot, the hand had recovered to T1 = 12.5%. In a previous study using d-tubocurarine, Walts et al.6 showed that, following recovery in the hand to T1 = 10%, full recovery can be obtained with the administration of reversal drugs.

Recovery of neuromuscular function in the hand has been correlated to recovery of adequate respiratory function.7,8 This study demonstrated that, after an intubating dose of vecuronium, the foot may be used as an alternative site for monitoring neuromuscular function to accurately assess reversibility of neuromuscular blockade, such that recovery of mechanical respiratory function is assured. Additional studies are needed to examine dose-response and dose-duration curves comparing these two muscles.

In summary, although some variability was found between hand and foot recovery from nondepolarizing blockade with vecuronium, assessment of neuromuscular function by monitoring large toe plantar flexion response to stimulation of the posterior tibial nerve may be a clinically useful alternative when the hand is not readily accessible.

### REFERENCES