Electrode Polarity and Peripheral Nerve Stimulation

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Quantitating neuromuscular blockade by assessing strength of muscle contraction is a well-established clinical practice. Important among the factors that influence muscle response are the location of the electrodes and the intensity of the electrical current. Since the peripheral nerve stimulator uses direct current, the polarity of the electrodes should also be important. The purpose of this study is to determine whether the electrode polarity of the peripheral nerve stimulator affects the twitch tension of the thumb in response to stimulation of the ulnar nerve.

METHODS

Nine surgical patients without known neuromuscular disease were studied. The protocol was approved by the University Committee for the Protection of Human Subjects. After induction of anesthesia, to insure nerve contact, two 25-gauge steel-hubbed needle electrodes were inserted subcutaneously (fig. 1): one at a right angle across the ulnar nerve at the wrist (A) and another 5 cm proximally (B). Additional electrodes were placed in the olecranon groove (C) and in the hypothenar eminence 3 cm distal from the electrode at the wrist (D).

The adduction response of the thumb to electrical stimulation was recorded with a Grass FT 03 force displacement transducer. Single stimuli of 0.2-ms duration delivered every 5 s (0.2 Hz) were applied by using a Professional Instruments peripheral nerve stimulator. The voltage was adjusted to 10 per cent greater than that required to evoke a maximal twitch response.

During the initial recording, the polarity of the electrode at the wrist was always negative. After each stimulation, the polarity was reversed by means of a manual switch. Responses to single-twitch stimuli were recorded so that a common electrode, A, was always at the wrist and was paired alternately with the other three electrodes, thus forming the combinations of AB, AC, and AD (fig. 1).

A total of six responses were recorded for each. After twitch height was determined for AB, AC, and AD in this manner, incremental doses of pancuronium (1–2 mg) were injected intravenously until the twitch height decreased to about 50 per cent of the control values. When twitch height was no longer diminished, the procedure was repeated. In three patients, additional electrodes were also placed, one 5 cm proximal to that in the olecranon groove and one in the deltoid muscle on that side. Twitch responses for the supracleocranon electrode paired with the one in the olecranon groove and for the deltoid muscle electrode paired with the one at the wrist were then recorded. Twitch-height responses were analyzed for each pairing of the electrodes by using an analysis of variance. When a significant F value was obtained, a paired t test was performed. Statistical significance was accepted when P was less than 0.05.

RESULTS

The mean twitch-height recordings for each pairing of the electrodes before pancuronium administration are

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Key words: Equipment: electrical, nerve stimulator. Measurement techniques: neuromuscular blockade. Monitoring: stimulator, nerve.
listed in table 1. Polarity had no significant effect on twitch height when the electrodes were spaced 5 cm apart at the wrist over the ulnar nerve (AB). In contrast, twitch-height response was significantly less when the needles were placed at the olecranon groove (AC) and the hypothenar eminence (AD).

The differences in twitch height with the electrodes at the olecranon groove and the hypothenar eminence were highly significant when polarity was reversed (table 2). In each case, a greater twitch height was obtained when the polarity of the electrode over the ulnar nerve at the wrist was negative.

Pancuronium did not interact with the effect of polarity on twitch height when the electrodes at the wrist and the olecranon groove were paired. However, pancuronium modified the effect of polarity slightly when the electrodes at the hypothenar eminence and the wrist were paired (see table 2—Po × Pa). This comes about by the fact that the pancuronium diminished the twitch height regardless of the electrode pairing. Since muscle contractions were almost abolished with the positive electrode at the wrist, the ratio of the twitch heights was decreased and when analyzed statistically was interpreted as an interaction.

**DISCUSSION**

Rosenberg and Greenhow² have examined the positioning and polarity of electrodes. By using a pad electrode and a needle electrode, the greatest muscle contraction occurred when the polarity of the electrode at the wrist over the ulnar nerve was negative. However, when pads were used for both electrodes, greater muscle contraction resulted with a negative polarity at the median nerve.

We used needles for both electrodes. Maximal twitch height was obtained when the negative (active) electrode was close to the ulnar nerve at the wrist and the positive (inactive) electrode was elsewhere; a minimal response was obtained with the positive electrode over the wrist. Reversing the polarity of the electrodes spaced 5 cm apart at the wrist probably had little effect because both electrodes were close to the ulnar nerve.

In the case of the three patients with the additional electrodes, twitch height was decreased markedly when the positive electrode was at the wrist and the negative electrode was over the deltoid muscle. When the electrodes at the olecranon area were paired, reversing polarity had little effect on twitch height. This finding can be explained on a physiologic basis.

Nerves usually are stimulated with needle electrodes lying adjacent to the nerve under the skin rather than by direct contact with the nerve. In this situation, electrical stimulation initiates an action potential by causing a flow of ions through the nerve membrane. When one electrode is placed over the nerve, it concentrates the current on the nerve and is called the active electrode. Electrodes positioned at a distance from the nerve are called inactive or indifferent electrodes. These electrodes do not concentrate current on the nerve.³ Nerve excitation always arises from the active electrode, whether it is used as cathode (negative) or anode (positive).

The cathode generates a depolarizing current that excites the nerve fiber, whereas an anodal current makes the fiber more resistant to excitation than normal. When the active electrode is negative, current passes through

**TABLE 1. Mean Twitch Height Responses (mm) of Nine Patients Before Pancuronium With Electrodes Paired in Three Ways**

<table>
<thead>
<tr>
<th>Electrode Pairings*</th>
<th>Polarity</th>
<th>Wrist (AB)</th>
<th>Olecranon (AC)</th>
<th>Hypothenar Eminence (AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>24</td>
<td>23</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>23</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

* Refer to figure 1 for the configuration of the electrodes.

**TABLE 2. An Analysis of Variance Showing Significance Levels (P Values) of Twitch Height Responses Associated with Electrodes Paired in Three Ways**

<table>
<thead>
<tr>
<th>Degrees of Freedom</th>
<th>Electrode Pairings*</th>
<th>Wrist (AB)</th>
<th>Olecranon (AC)</th>
<th>Hypothenar Eminence (AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient effect</td>
<td>8</td>
<td>0.0001</td>
<td>0.0150</td>
<td>0.35</td>
</tr>
<tr>
<td>Polarity effect (Po)</td>
<td>1</td>
<td>0.36†</td>
<td>0.0001†</td>
<td>0.01†</td>
</tr>
<tr>
<td>Pancuronium effect (Po)</td>
<td>1</td>
<td>0.0001†</td>
<td>0.0001†</td>
<td>0.001‡</td>
</tr>
<tr>
<td>Po × Pa</td>
<td>1</td>
<td>0.80‡</td>
<td>0.11†</td>
<td>0.03‡</td>
</tr>
</tbody>
</table>

* Refer to figure 1 for the configuration of the electrodes.
† No statistically significant effect on twitch height.
‡ Statistically significant difference in twitch height response between pairings.
the nerve in such a way that a cathodal current, the so-called real cathode, is set up on the upper surface of the nerve near the electrode. At the same time, an anodal current, the so-called virtual anode, is generated on the lower surface of the nerve and the more distal nerve segments. Pfluger's Law describes the difference in the effectiveness under the real cathode: a low current is sufficient on closure of the circuit to incite stimulation since the current stream is quite dense at this point and the cathodal current facilitates excitation. Conversely, under the anode a stronger current must be applied on closing the circuit as the anode tends to make the nerve less excitable (by hyperpolarizing it). However, the true anode generates a virtual cathode on the lower surface of the nerve that can stimulate the nerve, but by a low current density that leads to a weak response.

In our experiment, true anodal stimulation must have occurred when the positive electrode (true anode) over the ulnar nerve was paired with a negative electrode (true cathode) placed away from the nerve, for instance over the deltoid or hypothenar muscle. With the positive electrode stimulating the ulnar nerve the twitch was markedly attenuated.

We conclude that, during peripheral nerve stimulation, the active, negative electrode should be placed at the wrist over the ulnar nerve for maximal twitch response of the thumb. Increasing the distance of the electrode from the ulnar nerve lessens the current density and reduces the twitch height. If the polarity of the electrodes is unknown, the electrodes can be tested by alternately reversing polarity to determine which pair produces maximal muscle response. Perhaps the manufacturers of peripheral nerve stimulators should identify the anode and cathode connections. Failure to appreciate differences in polarity might result in muscle responses that could lead the anesthesiologist to overestimate the effect of the muscle relaxant during maintenance as well as to underestimate reversal following antagonist administration.

References