Staple electrodes: an innovative alternative for intraoperative electrophysiological monitoring

Technical note

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Intraoperative electrophysiological monitoring is essential for minimally invasive neurosurgery. The authors developed an innovative recording method using a staple electrode, consisting of a surgical skin staple and an integrated circuit (IC) test clip with a cable. The staple is put on the patient’s skin after the induction of general anesthesia. After head fixation, the IC test clip is simply hooked to the staple. The authors used this method for recording in 158 consecutive cases. It took only a few minutes to set up 4–18 staple electrodes in each case. None of the staple electrodes became disconnected unintentionally, and the initial impedance was kept throughout the procedures. The authors conclude that the staple electrode is superior to conventional disc or needle electrodes in speed of setup, electrical stability, and cost-effectiveness and recommend its routine use for intraoperative electrophysiological monitoring.

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KEY WORDS • electrode • intraoperative electrophysiological monitoring • surgical staple

Prevention of postoperative neurological deficits is essential in neurosurgery. With IEM, it is possible to directly evaluate patients’ neurological function while they are in a state of general anesthesia. Somatosensory evoked potential, ABR, MEP, and VEP have been developed for IEM. Improvements in electrophysiological devices and in our knowledge regarding the use of anesthetic agents during various types of electrophysiological monitoring have made IEM a routine procedure.

It is often difficult to maintain a stable connection of the electrode during neurosurgical procedures. Connection of an electrode near the operative field may be interrupted by blood as well as surgical maneuvers. It may be difficult to inspect and replace electrodes because they are located under a sterilized drape. To surmount these difficulties and optimize setup time and cost-effectiveness, we developed a new recording method using a device that we call a “staple electrode.”

Materials and Methods

The staple electrode consists of a surgical skin staple and an IC test clip, which is soldered to a cable (Fig. 1). Any surgical staples made of stainless steel may be used as long as they are not insulated. The IC test clip, which is widely used to test the flow of electrical current, has a spring-loaded hook for connecting to the electric circuit. The hook is opened by pushing the clip body with the fingers and closed by releasing. We used Leukoclip (Smith and Nephew, P.L.C.) as a skin staple, MJ-033 (Miyama Electric Co., Ltd.) as an IC test clip, and the cable from a used disposable needle electrode (NE 223S, Nihon Kohden Corp.), all commercially available.

Preclinical Testing

The mechanical strength (resistance to pulling force) and electrical resistance of the device were assessed in preclinical testing. One male Sprague–Dawley rat (12 weeks of age) was used for the mechanical strength testing; the animal had been used in a brain study and was killed immediately before being used in the current study. Four staple electrode devices (each consisting of a staple, IC test clip, and cables) were tested in the following manner: The surgical staple was attached to the rat’s (unshaved) body, which was fixed to a table,
and the cable was pulled taut and attached to a common spring scale. Graduated weights were placed on the scale to test resistance to pulling force. Electrical resistance of the staple electrode was measured in 6 of the devices using a common electrical testing unit.

**Clinical Experience**

From April 2004 to December 2006, IEM was performed in 164 patients in Shinshu University Hospital. The staple electrodes were used as a recording electrode in 158 consecutive patients for recording SEP (81 patients), ABR (42 patients), MEP (76 patients), and VEP (31 patients). After induction of general anesthesia, the staples were put on the appropriate recording sites without shaving any hair from the site (Fig. 2A). Next, the patient was positioned and his or her head was fixed in the head frame. Then, each staple was pinched with the hook of the IC test clip (Fig. 2B and C). The operative field was scrubbed and disinfected with little attention to the staple electrodes (Fig. 2D). All clinical data were collected and analyzed using a Neuropack Sigma recording system (Nihon Kohden Corp.). After...
surgery, the IC test clip was removed from the staple and the staple was removed from the patient’s scalp. The IC test clip and cable were washed and reused.

**Results**

**Preclinical Testing**

The mean electrical resistance of the 6 staple electrodes tested was 0.5 ± 0.1 ohm. In the physical strength test of the staple electrode on rat skin, the mean maximum permissible force against cable pulling for the 4 units tested was 18 ± 2.0 N. The hook of the IC test clip became stretched and disconnected from the staple when pulling force exceeded 20 N (2 kg weight); there was no laceration of the skin.

**Clinical Experience**

It took 1–4 minutes to set up 4–18 staple electrodes in each of the 158 patients in our case series. Impedance of staple electrodes was rarely > 5 kiloohm after the initial setup. Reduction of hair pinching with a staple or restapling could decrease the impedance < 5 kiloohm. The quality and signal-to-noise ratio of the data obtained with the staple electrode were almost equal to that of other conventional electrodes (Fig. 3). None of the staple electrodes became unintentionally disconnected, and the initial impedance was kept stable during surgery. There were no complications such as wound, bleeding, infection, or electrical injury due to the use of the staple electrode. Although we could not record electrical response in 7 patients (1 in SEP, 1 in ABR, 3 in MEP, and 2 in VEP), the reasons for the failure proved not to be related to use of the staple electrode. In a patient with failed SEP monitoring, latency of preoperative SEP of lower-extremity stimulation already had been prolonged and the amplitude had been diminished. In a failed case of ABR, the earphone cable was found disconnected. In the patients with MEP failures, preoperative moderate motor weakness and unsatisfactory placement of a stimulation electrode was noted. In 2 failures of VEP, the light-emitting diode goggles were dislodged by the reflected skin flap.

**Discussion**

Placement of an intraoperative electrode should be simple, stable, safe, quick, and cost-effective. Conventional methods using disc electrodes, spiral electrodes, and needle electrode were almost equal to that of other conventional electrodes (Fig. 3). None of the staple electrodes became unintentionally disconnected, and the initial impedance was kept stable during surgery. There were no complications such as wound, bleeding, infection, or electrical injury due to the use of the staple electrode. Although we could not record electrical response in 7 patients (1 in SEP, 1 in ABR, 3 in MEP, and 2 in VEP), the reasons for the failure proved not to be related to use of the staple electrode. In a patient with failed SEP monitoring, latency of preoperative SEP of lower-extremity stimulation already had been prolonged and the amplitude had been diminished. In a failed case of ABR, the earphone cable was found disconnected. In the patients with MEP failures, preoperative moderate motor weakness and unsatisfactory placement of a stimulation electrode was noted. In 2 failures of VEP, the light-emitting diode goggles were dislodged by the reflected skin flap.
Staple electrodes for intraoperative monitoring

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Disc</th>
<th>Needle</th>
<th>Spiral</th>
<th>Staple</th>
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<td>speed of setup</td>
<td>poor</td>
<td>fair</td>
<td>good</td>
<td>excellent</td>
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<tr>
<td>lack of interference during head fixation</td>
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<td>fair</td>
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<td>excellent</td>
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<tr>
<td>stability during surgery</td>
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<tr>
<td>cost-effectiveness</td>
<td>excellent</td>
<td>poor</td>
<td>good</td>
<td>good</td>
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</table>

TABLE 1

Characteristics of various recording electrodes

The staple electrode, however, is considered superior to conventional electrodes as summarized in Table 1.

The staple electrode can be set up more quickly than conventional electrodes. It took at least 2 minutes to set 1 disc electrode in our experience. Spiral or needle electrodes can be set more quickly than disc electrodes, but it usually took us 1 minute. On the other hand, 1 staple electrode can be set up in only 10 seconds. The staple electrode enables the surgeon to start surgery much sooner than conventional electrodes.

The electrode is usually placed between induction of general anesthesia and head fixation because determination of appropriate recording sites and adequate connection of the electrode become difficult after head fixation. The surgeon must be careful not to touch electrodes or pull cables during head fixation when conventional electrodes are used. On the other hand, when the staple electrode method is used, the surgeon can easily move a patient’s head during head fixation without concern for the electrode because the staples are only placed on the scalp and are not attached to the IC test clip until after head fixation.

Electrical stability is essential for quantitative analysis of IEM. Impedance of disc electrodes is increased by blood, antiseptic solution, and sweat secretion during surgery. Furthermore, disc and needle electrodes may be dislodged by surgical maneuvers. It is bothersome to set up these electrodes once they have become dislodged because they are located under a sterilized drape. Excessive stability, as when electrodes are too rigidly fixed, may cause skin laceration when the electrode is accidentally pulled. Staple electrodes did not cause any such skin injury in our animal experiments or in clinical use.

The cost of 1 staple electrode is <$1.50. In contrast, 1 needle electrode costs ~$20 and 1 spiral electrode costs ~$40 in Japan. It is strictly recommended to dispose of medical needles after use to reduce the risk of needle burial and infection.

Conclusions

The staple electrode represents a cost-effective and superior alternative to conventional electrodes for intraoperative electrophysiological monitoring and its routine use is recommended.

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Disclaimer

None of the authors has any financial interest in any device described in this paper.

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