Intraoperative Recording of Evoked Compound Action Potentials as a Tool to Aid Paddle Placement for Spinal Cord Stimulation

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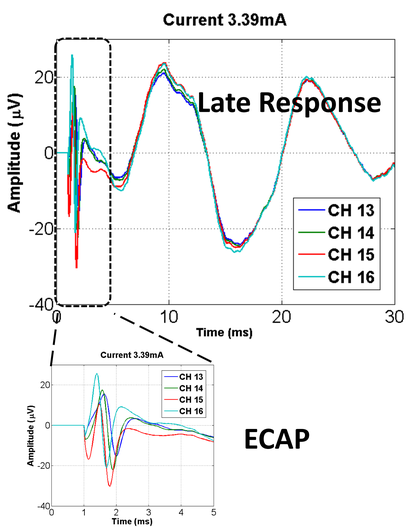
Introduction

Midline placement of paddle leads is important to provide optimal pain relief and to avoid uncomfortable side-effects during stimulation. Midline placement is routinely done by looking at anatomic features using fluoroscopy. In some cases Somatosensory Evoked Potential (SSEPs)[1,2] and Electromyography (EMG)[2] have been used to identify the physiologic midline.

Here we present data from two patients, in which midline placement was evaluated using a new technique of recording Evoked Compound Action Potentials (ECAPs) from the paddle lead.

We have previously observed that responses recorded within the first 3 milliseconds after stimulation are ECAPs representing signals travelling rostrally and caudally away from the stimulus on the dorsal column *(Aβ)* fibres.[3] Later responses after 5 milliseconds are ECAPs that can be caused by high current stimulation (See Figures below). We have previously observed that these signals are communicated laterally through the dorsal roots, do not propagate rostrocaudally, and are uncomfortable.[3]



Methods

Data was collected as part of an IRB approved protocol at Thomas Jefferson University. Each patient had been previously approved for the implantation of a spinal cord stimulator to treat their pain. Each patient was anesthetized and prepared for surgery. The implanted paddle leads were connected to a Saluda Medical MCS stimulating and recording system during the surgery, and evoked responses were monitored.

Patient 1 was implanted with St Jude Medical leads: an S4 Lamitrode™ lead, anterograde over C6 to C7; and an S8 Lamitrode™ lead, retrograde over T1 to T2. ECAPs were recorded on the S8 Lamitrode™ during the procedure and while closing. Stimulation was provided on either the S4 or S8 Lamitrode™.

Patient 2 was implanted with a St Jude Medical Penta™ lead, anterograde over T8. We provided bipolar stimulation at the top of the paddle on electrodes on the middle of the paddle and on electrodes on either side of the middle. We recorded ECAPs on electrodes in line and lateral to the stimulating electrodes.

Results – Recording Late Responses

Stimulating on the S8 Lamitrode™ showed no significant difference in ECAP amplitude between the procedure and closing for similar current amplitudes and no sign of a late response. (See Figure A.)

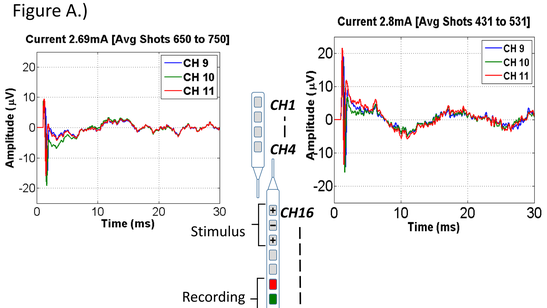


Figure A. Recordings after stimulation on the S8 Lamitrode™, during procedure (left) and at closing (right). Signals are ECAPs propagating from CH11 to CH9

Stimulating on the S4 lead during the procedure, late responses were observed at 3.9mA. (Not shown.) However, these were significantly smaller (<50%) than those observed during closing at 2.2mA (less than 60% of that current). (See Figure B.)

Stimulating on the S4 lead during closing, we observed a decrease in the amplitude of the ECAP and an increase in the late response. The appearance of late responses coincided with an increase in muscle activity – observed as twitching in the patient. (See Figure B.)

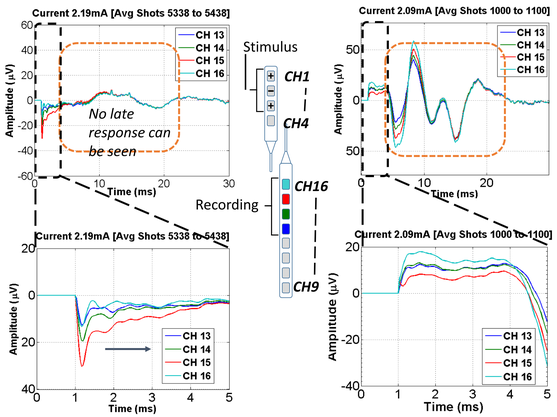
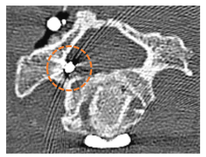


Figure B. Recordings after stimulation on the S4 Lamitrode™, during procedure (left) and at closing (right). During the procedure, ECAPs can be seen propagating from CH16 to CH13, but there is no late response. During closing, no ECAP signals can be seen propagating, but late responses and patient twitching were observed.

CT Imaging of Lead Location

The appearance of large, low threshold late responses when stimulating with the S4 lead suggested that it had moved laterally during closing and was activating dorsal root fibers.

CT imaging at C6 showed that the lead was lateral to the left of the midline and close to the dorsal roots



Results – Recording ECAP Amplitude In-Line vs Laterally

Data from Patient 2 with a Penta™ lead showed that the amplitude of the ECAPs recorded on the electrodes in line with the stimulation were larger compared to those on either side (more lateral).

The ECAP latency remained the same, indicating that the spinal cord sites at the recording electrodes were the same distance from the spinal cord sites at the stimulating electrodes, on both sides. We believe this indicates that the paddle lead was aligned with the physiological rostrocaudal axis. CT scans taken after the procedure found that the paddle lead was aligned straight along with the anatomical midline.

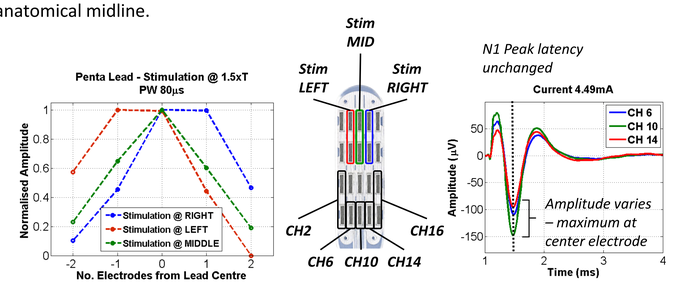


Figure C. ECAP Amplitude correlates with lateral distance from the stimulating electrode, on both sides (left). ECAP latency does not vary with the lateral distance from the stimulating electrode (right).

Conclusions

- The proximity of the lead to the dorsal roots creates dorsal root activation at lower currents. Dorsal root activation can be monitored as a late response in the ECAP signal.
- This technique, when used continuously during the procedure, may help to detect lateral movement of the lead.
- ECAP data may help to determine the orientation of the lead with respect to the physiological rostrocaudal axis of the spinal cord.
- The advantages of ECAP monitoring during lead placement include:
  1. It is continuous and dynamic
  2. There is no radiation
  3. Measurements are taken directly using the implanted SCS leads.

References

1. Balzer JR, Tomycz ND (2011) Localization of cervical and cervicomedually stimulation lead for pain treatment using median nerve somatosensory evoked potential collison testing. J neuroSurg 114:5.
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3. Parker JL, Karantonis DM, Single PS, Obradovic M, & Cousins MJ (2012) Compound action potentials recorded in the human spinal cord during neurostimulation for pain relief. Pain, 153(3), 593–601.