Percutaneous flexible bipolar epidural neuroelectrode for spinal cord stimulation

Technical note

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This article describes a new flexible bipolar neuroelectrode which is inserted percutaneously into the epidural space for segmental spinal cord stimulation. This electrode was used in experiments with dogs and monkeys for recording cortical somatosensory evoked potentials in order to identify intraoperative spinal cord ischemia during periods of aortic occlusion.

KEY WORDS • spinal cord stimulation • epidural bipolar neuroelectrode • somatosensory evoked potentials • aortic occlusion • spinal cord ischemia • intraoperative monitoring

Cortical somatosensory evoked potentials (SEP's) are a sensitive indicator of spinal cord ischemia during aortic occlusion. Measuring cortical SEP's in response to stimulation of the tibial nerve during cross-clamping of the thoracic descending aorta is limited by several factors. 1) After 20 minutes of occlusion, cortical SEP's are lost due to ischemia of the peripheral nerve. 2) Latency and amplitude of the tracings vary with changing levels of anesthesia. 3) Long conduction distance from the foot to the brain sometimes masks the effect of spinal lesions. An alternative to tibial nerve stimulation is spinal cord stimulation with a percutaneous flexible bipolar neuroelectrode inserted into the epidural space. We describe our experience with cortical SEP's in monkeys and dogs.

Materials and Methods

Experiments were performed on adult German Bernhardiner dogs (each weighing 50 to 55 kg) and healthy Macaca fascicularis monkeys (each weighing about 5 kg). Anesthesia was induced with thiamylal (Surital, 16 mg/kg) and phencyclidine (Ketanest, 10 mg/kg). Endotracheal anesthesia was maintained with enflurane (0.5% to 1.0%). A skin surface bipolar electrode was placed on the popliteal fossa for stimulation of the tibial nerve. Under sterile operating conditions, an epidural No. 17 cannula (with Crawford or Tuohy bevel) was used for puncture of the epidural space. The flexible bipolar electrode* (length 120 cm, diameter 0.9 mm, inter-electrode distance 5 mm) was then inserted through the cannula (Fig. 1). The tip of the electrode was placed at the T12-L1 vertebral level for detection of spinal cord ischemia after the descending aorta was clamped. This level was selected because clamping of the descending aorta interrupts blood flow through the artery of Adamkiewicz, and may cause critical spinal cord ischemia. Once the epidural space was entered, the cannula was removed. Electrode positions were confirmed on x-ray films before and after the recording session to assure constant conduction placement (Fig. 2).

Results

Cortical SEP's were measured in both species before and during aortic occlusion with a clinical evoked potential system.† Recordings from stimulation of the peripheral tibial nerve were compared to recordings from stimulation of the spinal cord. In either case the response was recorded from a parietal electrode in the midline of the scalp (CZ') to the frontal electrode (FZ). For cortical SEP recording, a stimulus of 50 V was applied to the tibial nerve and a 4-V square-wave shock

* Flexible bipolar electrode manufactured by Vygon: Medizinische Chirurgische Werke D — 5100 Aachen, Goebbelgasse 100, West Germany.
† Evoked potential system supplied by Medelec, Ltd., Surrey, Great Britain.
to the spinal cord at a rate of 2/sec, with a duration time of 0.2 msec and amplified (gain 10,000, bandpass 20 Hz to 2 kHz). A time scale of 10 msec was used, and between 128 and 632 responses were averaged.

The introduction of the flexible bipolar electrode into the epidural space was technically not difficult in either dogs or monkeys. The tip of the electrode could be placed easily at any level. The cortical response of the tibial nerve conforms in shape to that of spinal column stimulation, but is different in peak latency and amplitude. The peak latency with spinal cord stimulation is earlier and the amplitude is much greater (Fig. 3). Amplitudes of cortical SEP's ranged from 1.8 to 15.0 nV on tibial nerve stimulation and from 6.8 to 50.0 nV on spinal cord stimulation (Fig. 4). After 20 minutes of aortic occlusion, the cortical response to spinal cord stimulation remained unchanged, whereas the potential evoked by tibial nerve stimulation had disappeared.

Discussion

Spinal cord stimulation with monopolar epidural neuroelectrodes or with a reference electrode taped on the skin surface is often needed for clinical examination, including evaluation of pain control, paraplegic spasticity, spinal cord injury, and spinal cord ischemia. In most cases, laminectomy is necessary to place an epidural electrode in the spinal column. We have found...
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Fig. 3. Cortical somatosensory evoked potentials in response to tibial nerve stimulation (left) and spinal cord stimulation (right) in monkeys.

Fig. 4. Cortical somatosensory evoked potentials in response to tibial nerve stimulation (left) and spinal cord stimulation (right) in dogs.

It is easy to insert the bipolar electrode through a No. 17 cannula by a paramedian approach into the epidural space without any surgical intervention. We used the loss-of-resistance guidance method for making the puncture, which is a well known technique for catheter placement for anesthesia. We were able to reach any level of the epidural space by this method.

This method of puncturing the epidural space for placement of a flexible neuroelectrode has been described by others. In all previously reported cases a monopolar electrode was used, which needs a reference electrode on the skin surface and therefore does not offer the same quality of evoked potential monitoring. Monopolar recordings from a reference in the paravertebral muscle or on the skin surface reduced cortical SEP amplitude and signal resolution. The distance between different and indifferent poles was 5 mm in our experiments. The inter-electrode distance is designed to be variable so as to provide stimulation of various segments of the spinal cord. This device may also be useful for stimulation of the posterior columns of the spinal cord for pain control. The applicability of this flexible bipolar electrode for intraoperative cortical SEP monitoring during thoracolumbar aortic cross-clamping will be evaluated in a later study.

References


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