Establishing a Porcine Model for Studying Intraoperative Nerve Root Injury Using Transcranial Motor Evoked Potentials

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Introduction: Nerve root injury is a significant neurologic complication of lumbosacral spinal surgery and can lead to persistent radicular pain, numbness, and weakness. While continuous intra-operative neurophysiologic monitoring of somatosensory evoked potentials (SSEPs), motor evoked potentials (MEPs), and electromyography (EMG) have been found to be useful in the prevention of spinal cord injury, SSEPs and EMG have limited utility in detecting nerve root injuries. Transcranial (tc) MEPs may provide sensitive and instantaneous information regarding the integrity of the motor system and are being increasingly used in the operating room [1]. Little data, however, exists regarding the signal thresholds that predict irreversible changes due to neurologic injury. Since controlled testing is not possible in the clinical setting, our objective was to develop an animal model to study intraoperative nerve root injury using tcMEPs.

Materials and Methods: 6 female 50 kg pigs were used in this study. After induction with isoflurane, all pigs were maintained under total intravenous anesthesia using fentanyl, propofol, and ketamine. Customized electrodes were placed in burr holes over the motor cortex (fig 1a). Wire leads were attached to a constant-voltage multi-pulse transcranial stimulator (Digitimer D-185, Digitimer LTD, Welwyn Garden City, UK). Spontaneous and evoked muscle potentials were recorded using subdermal electrodes (Medtronic-Xomed, Rochester, MN) placed approximately 4-6 cm apart in the hind legs bilaterally (fig 1b). A stimulation train of 3-5 pulses was delivered through the skull electrodes and adjusted to determine the minimum threshold level needed to elicit reproducible MEP responses. The evoked responses were recorded via an electrophysiological recording platform (Cadwell Cascade, Cadwell Laboratories Inc., Kennewick, WA) every 30 seconds. Amplitudes from crest to trough were calculated. In addition, EMG was performed with a monopolar ball-tip probe (Medtronic, Minneapolis, MN) configured to a constant current stimulator at duration of 200 microseconds and rate of 4.1 Hz. Thresholds were based upon the production of a compound muscle action potential that approximated 50 microvolts in amplitude from baseline. Decompression was performed using a mid-line posterior approach to expose the L3-S1 nerve roots. Lumbar nerve roots on one side were ligated sequentially from proximal to distal (n=3) or distal to proximal (n=3) with nylon suture. The corresponding myotomes were measured after ligation of each nerve root. While still under general anesthesia, the animals were euthanized with pentobarbital and bilateral thoracotomies.

Results of mapping experiments. After nerve root ligation, the myotome which showed largest change from the previous MEP is shown.

Discussion: Here we present a large animal model to study intraoperative nerve root injury. Our results validate the use of tcMEP monitoring of multiple myotomes to detect nerve root injury in pigs. While some cross-innervation was observed, ligation of a single nerve root led to reproducible changes in the corresponding myotomes. In all pigs, ligation of the L5 nerve root led to consistent decreases (mean 85%) in MEPs from TA and was specific for L5. Thus, this nerve root-myotome may represent the most useful level for studying nerve root injury via tcMEPs. In order to maximize clinical applicability, we utilized a large animal model and selected the pig based on its high degree of similarity to human nerve roots [2]. In addition, the anesthetic regimen, neuromonitoring equipment, and surgical technique are nearly identical to those utilized in the operating room. Therefore, we ultimately seek to extrapolate these findings into clinical practice. This model will be used to study thresholds and warning signs associated with nerve root injury during nerve root retraction as well as to study preventative therapeutics and strategies.


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