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Epidural D-Wave Recordings for Intramedullary Spinal Cord Tumors

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INTRODUCTION

Direct or D-waves represent the direct activation of the corticospinal tract fibers that are recorded directly from the exposed spinal cord. While not as widely employed as the main intraoperative neuromonitoring motor function modalities such as motor evoked potentials (MEPs) or electromyography (EMG), epidural D-waves can provide just as much benefit to spinal monitoring cases. While MEPs and EMG record from the muscles, D-waves only record from the level of the epidural electrode on the spinal cord. While this may seem limited, D-waves carry their unique advantages (Figure 1). As a direct recording, the D-waves do not experience the same synaptic delay that MEPs experience at the ventral horn. Thus, there is little to no delay in the feedback of D-waves recordings. As a direct waveform, it requires little to no averaging, so there is less delay than for modalities that do. The single pulse stimulation needed to elicit a D-wave response also has less risk of causing patient movement unlike MEPs and thus can be run continuously without worry[1]. This can detect warning changes potentially indicating compromised motor function sooner before it appears in the muscle recordings.

Anesthetic influence on evoked potentials has been well-documented in the literature, especially inhalational anesthesia as it causes suppression of signals, and throughout a procedure, can cause an “anesthetic fade” - a diminishing effect on MEPs even when anesthetic concentrations are kept constant[2]. However, D-waves do not show the same decrease in response to increased anesthetic levels. Similarly, while muscle relaxants act at the neuromuscular junction and block MEP and EMG recordings, D-waves do not suffer from the same problem as recording takes place before the signal reaches the neuromuscular junction. D-waves also show less susceptibility to changes in physiological factors such as body temperature and blood pressure relative to MEPs and EMG[3], and at most, may see a slight

change in latency[4]. The stability of D-waves lends itself to feasible reproducibility during surgical procedures. In cases where MEPs are poorly defined or absent, D-waves provide a reliable and quick alternative for monitoring motor pathways in cases where MEP responses are not enough[5].

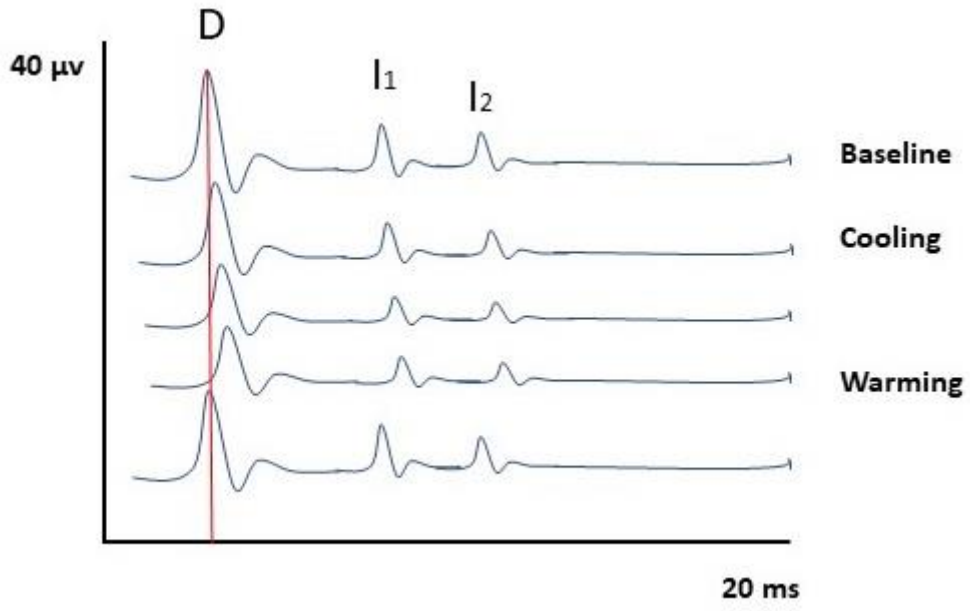

Figure 1: D-waves and I-waves over the lower cervical spinal cord in a C3-C4 intramedullary spinal cord tumor patient. Delayed D and I waves latencies can be seen due to temporary cooling of the exposed spinal cord. The latencies of D and I waves returned to the baseline after warming the spinal cord [6].

As D-waves are direct recordings from the spinal cord, their invasive application is best used for cases that already require exposure to the spinal cord such as intradural intramedullary spinal cord tumor resection. Furthermore, D-waves cannot be recorded below the lower thoracic level where the cord ends so it cannot obtain signals from the level of the lumbar and sacral spinal segments. As with any IONM protocol, multimodality approaches yield the best results in sensitivity and specificity. Likewise, D-waves are best used in conjunction with MEPs and EMG rather than alone to offset their limitations. Alarm criteria for D-waves typically follow the general guideline of a 50 percent or more decrease in amplitude. As D-waves are direct recordings from the corticospinal tract fibers, decreases are interpreted as a compromise of motor function and a prediction of postoperative motor deficits. The meaning of D-wave changes is best understood when considered in the context of MEPs. While the loss of D-waves or MEPs can occur without changes in the other, it is typically indicative of postoperative motor deficit when a change occurs in both (Table 1). However, even if MEPs are absent at some point in the procedure, if D-waves remain relatively stable, the patient has a good prognosis for recovery from any motor deficit that may present

postoperatively. In high-risk procedures involving the exposed spinal cord such as intramedullary tumor resection, recording D-waves provides real-time and valuable information to supplement the protection of motor function integrity and should be strongly considered as part of the motor monitoring protocol when feasible.

D-wave	Muscle Response	Motor Status
Unchanged	Preserved	Unchanged
Unchanged	Lost on one or both sided	Temporary motor deficits
30-50% decrease	Preserved	Unchanged
30-50% decrease	Lost on one or both sided	Temporary motor deficits
>50% decrease	Lost	Long term motor deficits

Table 1: D-wave and muscle MEP changes with possible postoperative motor status [6].

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