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Clinical Study

# Intraoperative neurophysiologic monitoring with Hoffmann reflex during thoracic spine surgery

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ABSTRACT

The aim of this study was examine the role of Hoffmann reflex (H-reflex) monitoring in identifying intraoperative spinal cord injury and predicting postoperative neurological outcome in patients undergoing thoracic spine surgery. Despite the physiologic basis for the use of H-reflex to monitor spinal motor pathways, there are only a few reports highlighting its application as an intraoperative neuromonitoring tool. We retrospectively reviewed the electronic medical records of 19 consecutive patients who underwent thoracic spine surgery for metastatic thoracic spinal tumors between 2011 and 2013 at the MD Anderson Cancer Center. H-waves and somatosensory evoked potentials (SSEP) were simultaneously monitored in our series consisting of four female and 15 male patients aged 10–71 years. In 10 of 19 patients, bilateral H-waves and SSEP were stable throughout the monitoring. Five of 19 patients had a <50% transient reduction in H-wave amplitude that later returned to baseline. SSEP were absent from baseline throughout surgery in two of 19 patients. In our series, neither general anesthesia nor low dose muscle relaxants interfered with the H-waves. At 3 and 6 month follow-ups, none of the patients exhibited new postoperative neurological deficits. Stable intraoperative H-waves are suggestive of preserved postoperative neurologic outcomes. Intraoperative H-reflex monitoring could be a reasonable alternative especially when motor evoked potentials are unattainable. Given its greater sensitivity to spinal cord ischemia, relatively low cost and ease of acquisition, H-reflex monitoring could be a useful adjunct in during thoracic spine surgeries.

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## 1. Introduction

There are specific risks to the spinal cord and nerve roots during surgeries involving the spine. Complication rates vary with each type of procedure. For example, 1–15% of patients in a series experienced aggravated or *de novo* motor or sensory symptoms following various spine stabilization surgeries [1]. Crucially, debilitating spinal cord ischemia can occur during surgeries involving the thoracic spine due to injury to the artery of Adamkiewicz, a major vessel that supplies the spinal cord in the thoracolumbar region [2]. The role of intraoperative neurophysiological monitoring (IONM) during spine surgery is to evaluate the integrity of the spinal cord and nerve roots continuously while patients undergo procedures that have the potential to cause injury [3]. Somatosensory evoked potentials (SSEP) and transcranial motor evoked potentials (TcMEP) are considered the gold standard for intraoperative spinal cord monitoring [4], however, both techniques have limitations, including the inability to continuously and directly monitor for changes in motor function during spinal surgery. Furthermore, SSEPs and TcMEPs may be unattainable due to preexisting neurological deficits, technical limitations or contraindications. In such instances other IONM techniques including the Hoffmann (H)-reflex and F-waves have been successfully tried [5].

The H-reflex is the electrical analogue of the tendon jerk reflex, mediated through monosynaptic pathways in the spinal cord [6]. The afferent pathway involves electrical activation of the large 1a nerve fibers originating from muscle. After entering the dorsal horn of the spinal cord the 1a fibers synapse with the motor neurons. The efferent pathway involves orthodromic motor conduction through motor fibers in the same homologous spinal segment as the afferent pathway [6]. Electromyogram recorded during the H-reflex typically shows two responses: an initial M-wave resulting from direct stimulation of the motor axons innervating the muscle, and later H-wave, a measure of the alpha motoneurons activated by 1a afferents [4]. The reflex is most easily recorded from the

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gastrocnemius muscle following stimulation of the tibial nerve in the popliteal fossa [6]. Gastrocnemius and flexor carpi radialis H-reflexes are most commonly employed to monitor the integrity of the cord and nerve roots during spine surgery. In addition to monitoring the sensory and motor nerves, the H-reflex also monitors the spinal cord at the level of the reflex and cephalad [5]. A particular advantage of intraoperative H-reflex recording is that the recordings are single sweep [4]. These recordings are therefore real-time and there is no delay after the onset of spinal cord or nerve root compromise that is present when using averaged evoked potentials [5].

Previous human studies have shown that a >90% sustained suppression in intraoperative H-wave amplitude correlates with a postoperative neurologic deficit [7–9]. Moreover, several animal studies have demonstrated greater sensitivity of the H-reflex in detecting spinal cord ischemia than SSEP and TcMEP [10,11]. Furthermore, the H-reflex is least affected by general anesthesia, especially with non-halogenated anesthetics, as compared with TcMEP [8,12]. Despite the physiologic basis for its use to monitor spinal motor pathways, there are only a few reports highlighting its application as an IONM tool. As such, the aim of this study was to reexamine the role of H-reflex monitoring in identifying intraoperative spinal cord injury and predicting postoperative neurological outcome in patients undergoing thoracic spine surgery.

## 2. Methods

### 2.1. Study design

We retrospectively reviewed the electronic medical records of 19 consecutive patients who underwent thoracic spine surgery for metastatic thoracic spinal tumors between 2011 and 2013 at the MD Anderson Cancer Center, Houston, Texas, USA. Demographic information, preoperative diagnosis, intraoperative neurophysiologic changes, surgical approach and procedure, duration of surgery, and pre- and postoperative (at 3 and 6 months) neurologic status were collected.

### 2.2. Intraoperative monitoring techniques

In our cohort, H-waves and SSEP were simultaneously monitored. Bilateral H-waves were recorded from gastrocnemius muscles following popliteal fossa stimulation. The H-wave was elicited by intermittent percutaneous stimulation of the posterior tibial nerve at the popliteal fossa with an interelectrode distance of 2 cm. SSEP were recorded from scalp electrodes over the right and left somatosensory cortex with bilateral median/ulnar nerves at the wrist and bilateral posterior tibial nerves at the ankle. H-wave and SSEP stimulation was performed using disk electrodes. H-wave and SSEP amplitudes were carefully observed by a neurophysiology technician who immediately reported to the surgeon whenever drops in amplitude or signal disappearance were noted. A sustained >50% decrease in intraoperative SSEP amplitude, or a >90% sustained reduction in intraoperative H-wave amplitude was considered as a significant alarm.

### 2.3. Anesthesia

A single bolus of vecuronium or cisatracurium was given to the patients for endotracheal intubation. General anesthesia was induced with propofol or thiopental. In all patients general anesthesia was maintained with propofol and fentanyl.

## 3. Results

Our series consisted of four female and 15 male patients aged 10–71 years. In nine of 19 patients, metastatic tumors involved the T1–6 spinal levels, while 10 of 19 patients had T7–12 spinal level involvement. None of our cohort had evidence for tumor involvement in the thoracolumbar cord except in two patients who had clinical and radiologic evidence for thoracic myelopathy due to mass effect from their primary tumors (patient numbers 16 and 17; Table 1). However, in our series there was no evidence of intramedullary spread of a metastatic tumor. Preoperatively our cohort had normal muscle strength in the lower extremities with the exception of the two myelopathic patients.

In our series, five patients underwent combined laminectomy and facetectomy, six vertebrectomy with spine stabilization, three laminectomy with spine stabilization, one laminectomy and facetectomy, one paraspinal tumor resection and three laminectomy alone. Intercostal nerve root clamping was performed before cutting during which H-wave monitoring was more frequent. Average time of surgery was 7 hours 48 minutes (range: 2–12 hours) with an average IONM time of 4 hours 54 minutes (range: 1–8 hours). In 10 of 19 patients, bilateral H-waves and SSEP were stable throughout IONM. H-waves were recordable throughout surgery in all patients, however, five of 19 patients had a <50% transient reduction in H-wave amplitude that later returned to baseline. Two of 19 patients had a <50% transient reduction in SSEP amplitude that later returned to baseline (Table 1). SSEP were absent from baseline throughout surgery in two of 19 patients. In our cohort, neither general anesthesia nor low dose muscle relaxants interfered with the intraoperative H-wave recordings. At 3 and 6 month follow-ups, none of our patients exhibited new postoperative neurological deficits including the two patients who had absent SSEP throughout surgery (Table 1).

In our cohort, a non-sustained <50% reduction in intraoperative H-wave amplitude wasn't associated with new neurologic deficit at the 3 and 6 month follow-ups. This rendered H-reflex monitoring to be very specific (100%) in predicting postoperative neurologic outcome for our series. Since none of our cohort had a >90% sustained suppression in the H-wave amplitude (a level that has been consistently shown to correlate with postoperative neurologic outcome), we were unable to quantify the sensitivity of H-reflex IONM. Two patients had absent SSEP from baseline throughout surgery, however, their intraoperative H-waves were stable throughout. Given that both patients had absent SSEP prior to their surgery combined with the stable intraoperative H-waves, we didn't consider the absence of intraoperative SSEP as an alarm for further cord compromise.

## 4. Discussion

The notion that the H-reflex can reliably monitor the integrity of rostral spinal motor pathways has strong physiologic support from several animal and human studies [5,6,11,13]. For instance, Leis et al. [8] has demonstrated that rostral cord injury rapidly suppresses the H-reflex and the degree and duration of suppression correlates with the severity of the injury. H-reflex has also been successfully employed to monitor the integrity of the spinal cord and nerve roots during spine surgeries at the thoracic level, rostral to the L5–S1 levels [11,14,15]. Following two landmark reports that highlighted the potential for the H-reflex to be a valuable intraoperative monitoring tool for surgeries involving the thoracolumbar spine, there was optimism about the possibility of its large-scale application [8,9]. However, the initial excitement has steadily waned for several reasons. Potential reasons for its limited