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Clinical Study

Verification of nerve decompression using mechanomyography

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Abstract

BACKGROUND CONTEXT: Assessment of nerve root decompression in surgery is largely based on visualization and tactile feedback. Often times, visualization can be limited, such as in minimally invasive surgery, and tactile feedback is a subjective assessment that makes the evaluation of successful nerve decompression difficult. Electromyography (EMG) has been proposed as an assessment tool, but EMG responses are often difficult to quantify. Alternatively, mechanomyography (MMG) provides a quantifiable response with high signal-to-noise ratio compared with EMG. MMG provides a sensitive tool to accurately quantify mechanical responses to motor action potentials generated by electrical stimulus, allowing more reliable assessment of nerve decompression.

PURPOSE: The aim of this study was to assess the ability of MMG to quantitatively demonstrate successful nerve root decompression.

STUDY DESIGN: Prospective cohort, Therapeutic Level III, Urban Level I Trauma Center.

PATIENT SAMPLE: A total of 46 patients (72 affected nerve roots) undergoing decompression procedures for lower extremity radiculopathy caused by nerve root compression were enrolled in the study. The study population included 15 patients with herniated nucleus pulposus (HNP) and 31 with lateral recess stenosis (LRS).

OUTCOME MEASURE: Visual analog scale (VAS) score.

METHODS: A total of 72 nerves roots in 46 patients undergoing lumbar decompression procedures, for lower extremity radicular symptoms, were tested using MMG. Nerves were stimulated upstream from the compression site, and the lowest threshold current needed to generate a muscle response was determined. Signal response sizes were recorded before and after decompression. VAS scores were collected pre- and postoperatively.

RESULTS: Of the patients, 90% (65/72) had elevated stimulation thresholds (>1 milliamp [mA]) before decompression. After decompression, 98% of patients (64/65) with elevated current thresholds exhibited a drop in threshold of ≥1 mA ($p<.001$). A postdecompression increase in response amplitude was recorded in all patients. VAS scores improved postdecompression (6.8 vs. 1.1, $p<.001$) with a positive correlation between decreased stimulation thresholds and degree of improvement in VAS scores ($p<.001$).

FDA device/drug status: Approved (Sentio MMG, Sentio, LLC, Wixom, MI).

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CONCLUSION: MMG is an effective tool that can be used to differentiate normal and compressed nerves by quantifying the mechanomyographic response to a stimulating current. MMG allows one to measure the effect of decompression, judge its effectiveness in real time, and eliminate the subjectivity seen in tactile feedback methods. When the adequacy of decompression is uncertain, MMG can guide the surgeon toward additional or alternative procedures to ensure complete nerve root decompression.

Keywords: Decompression; Electromyography (EMG); Mechanomyography (MMG); Nerve monitoring; Signal-to-noise lumbar spine

Introduction

Intraoperative neural monitoring (IONM) is a valuable tool during invasive spinal procedures [1–3]. In recent years, the use of minimally invasive techniques has increased dramatically due to its proven benefits [4–7]. The introduction of new surgical techniques requires the continued assurance of patient safety. As surgical techniques evolve, IONM technology must also evolve [8]. In addition to improving patient safety, more precise monitoring techniques may also provide the surgeon with information regarding the severity of nerve root impingement and efficacy of decompression.

In traditional open spine surgery, the assessment of decompression of nerve roots relies on direct visualization of nerves and on tactile feedback. These methods are subjective in nature and can be unreliable when faced with a smaller working zone such as during minimally invasive procedures. Electromyography (EMG) has been proposed as a method of testing nerves to determine if adequate decompression has been achieved [3,9–11]. Unfortunately, various technical and logistic considerations make EMG less desirable for use as a diagnostic test in the operating room (OR) [12]. Low signal-to-noise ratios are inherent to EMG; additionally varying levels of background electrical noise in the OR can make quantitative analysis of signal responses challenging (Fig. 1) [13–15]. EMG also requires the use of a technician in the OR, increasing the cost of the procedure. Additionally, EMG requires the use of needles, adding risk of needle stick injury to healthcare workers.

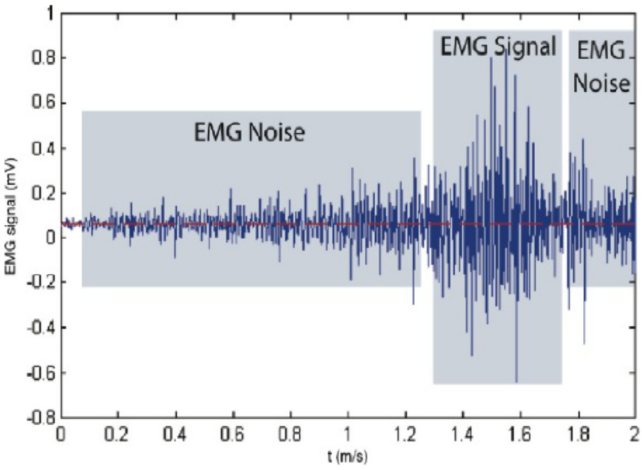

Fig. 1. Standard intraoperative EMG.

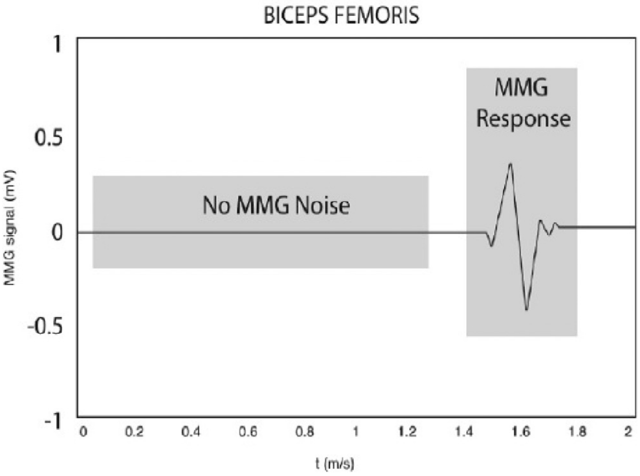

Fig. 2. Example of a typical response of muscle contraction as recorded by mechanomyography.

Mechanomyography (MMG) is an alternative method of measuring the response of muscle to motor action potentials in motor neurons [16,17]. MMG monitors the same physiological event that EMG monitors but does so using mechanical, accelerometer-based sensors to detect motion of the muscle itself (Fig. 2) [18–20]. As muscle fibers contract, they expand orthogonally. This change in shape and motion can be detected using surface-mounted sensors [17,21]. This method of monitoring drastically reduces the interference caused by surrounding electrical noise [22].

Advantages of MMG include a clear, noise-free signal that is reproducible even in the complex environment of the operating theater. MMG signals are easy to recognize and are also quantifiable, which allows for the localization of nerves without direct visualization [23]. A very high signal-to-noise ratio allows for a precise measurement, unaffected by background electrical noise [24]. Responses can be detected at very small currents allowing a precise determination of the stimulation threshold [25]. Previous studies have shown that the MMG response varies directly with the amount of stimulating current and the magnitude of that response can be measured using accelerometer-based sensors [16,19,23,25,26].