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Original article

Neural responses to the mechanical characteristics of high velocity, low amplitude spinal manipulation: Effect of specific contact site

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ABSTRACT

Background: Systematic investigations are needed identifying how variability in the biomechanical characteristics of spinal manipulation affects physiological responses. Such knowledge may inform future clinical practice and research study design.

Objective: To determine how contact site for high velocity, low amplitude spinal manipulation (HVLA-SM) affects sensory input to the central nervous system.

Design: HVLA-SM was applied to 4 specific anatomic locations using a no-HVLA-SM control at each location randomized in an 8×8 Latin square design in an animal model.

Methods: Neural activity from muscle spindles in the multifidus and longissimus muscles were recorded from L_6 dorsal rootlets in 16 anesthetized cats. A posterior to anterior HVLA-SM was applied through the intact skin overlying the L_6 spinous process, lamina, inferior articular process and L_7 spinous process. HVLA-SMs were preceded and followed by simulated spinal movement applied to the L_6 vertebra. Change in mean instantaneous discharge frequency (ΔMIF) was determined during the thrust and the simulated spinal movement.

Results: All contact sites increased L_6 muscle spindle discharge during the thrust. Contact at all L_6 sites significantly increased spindle discharge more than at the L_7 site when recording at L_6. There were no differences between L_6 contact sites. For simulated movement, the L_6 contact sites but not the L_7 contact site significantly decreased L_6 spindle responses to a change in vertebral position but not to movement to that position.

Conclusions: This animal study showed that contact site for an HVLA-SM can have a significant effect on the magnitude of sensory input arising from muscle spindles in the back.

1. Introduction

Spinal manipulation is a form of manual therapy used most frequently to treat musculoskeletal complaints (Hawk et al., 2001; Sorensen et al., 2006). It is most readily differentiated from spinal mobilization by use of an applied thrust and there is rationale to think that these two forms of treatment may not be equivalent either clinically (Cleland et al., 2009; Rubinstein et al., 2013; but see; Cook et al., 2013) or in their mechanisms of action (Bolton and Budgell, 2006) and therefore they should be studied individually. Utilization data indicate most patients who receive spinal manipulation receive a manual procedure relatively high in velocity and low in amplitude (HVLA-SM) (Shekelle et al., 1992; Eisenberg et al., 1998; Christensen et al., 2005). Following preloading of the spinal tissues, the clinician rapidly delivers a thrust to a target vertebra through a short lever arm by manually contacting the skin overlying that vertebra's lamina, spinous, transverse or mammillary process, with the intent of displacing the vertebra, gapping its facet joints, and creating mechanical, neurological and biological effects (Greenman, 1989; Leach, 2004; Hooper, 2005; Bergmann, 2005; Cramer et al., 2013).

The biomechanical parameters that characterize an HVLA-SM are considered fundamental to its application (Triano, 2000; Bergmann, 2005), yet they can vary greatly. For example in the low back, thrust forces reach a peak ranging from 220 to 889 N within 75–225 ms (Hessell et al., 1990; Conway et al., 1993; Herzog et al., 1993; Triano and Schultz, 1997). Even when an individual

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clinician delivers similar HVLA-SMs, biomechanical characteristics vary (Cambridge et al., 2012). In addition, an HVLA-SM may not be as targeted to a specific vertebra as intended. By the time a thrust is delivered, the actual contact site may have migrated up to 10 mm from the originally intended site (Herzog et al., 2001). How this variability affects the biological and therapeutic outcomes of HVLA-SM has yet to be determined and may be important to both clinical practice and research design.

Several groups using electromechanical devices to deliver controlled, repeatable HVLA-SMs (Pickar and Wheeler, 2001; Vaillant et al., 2010; Descarreaux et al., 2013) have been systematically investigating how variations in an HVLA-SM's biomechanical characteristics affect neuromuscular, biomechanical and neurophysiological responses. In healthy humans Descarreaux and colleagues found that increasing thrust force but decreasing either thrust duration or preload force produces linear increases in the magnitudes of EMG responses evoked during and following the manipulative thrust (Nougarou et al., 2013; Page et al., 2014; Francois et al., 2014). In a feline model, Pickar and colleagues found that as thrust duration approaches a value previously shown to be used clinically, a threshold increase in the sensory input from paraspinal muscle spindles occurs during the thrust (Pickar et al., 2007; Reed et al., 2013). While preload magnitude and duration interact to modulate muscle spindle activity during the thrust (Reed et al., 2014), preload, thrust duration, and thrust amplitude all appear to have minimal effect on changing the responsiveness of muscle spindles to spinal movement following the thrust (Cao et al., 2013; Reed et al., 2014). Also using a feline model Kawchuk and colleagues found that thrust duration interacts with thrust amplitude toward changing spinal stiffness (Vaillant et al., 2012). In addition, the specific contact site through which the thrust is applied determines whether spinal stiffness changes (Edgecombe et al., 2013). Currently nothing is known about the relationship between an HVLA-SM's contact site and any neural response.

The goal of the present study was to determine how the contact site through which the HVLA-SM's thrust is applied affects the response of paraspinal muscle spindles. Although the mechanistic pathways underlying the effects of HVLA-SM are not yet known, muscle spindles were chosen because changes in neural input arising from co-activated paraspinal sensory receptors (Korr, 1978; Haldeman, 1983; Gillette, 1987; Greenman, 1989; Pickar, 2002; Leach, 2004; Henderson, 2005; Bialosky et al., 2009; Pickar and Bolton, 2012), including muscle spindles (Korr, 1975), have long been thought to contribute to HVLA-SM's therapeutic effects. Studying sensory input from paraspinal tissues in humans has not been possible due to the invasive nature of the experimental procedures. We used a feline model to determine the effect of contact site on the response of muscle spindles both during and following the HVLA-SM. Thinking that a lever's mechanical advantage depends upon the length of its lever arm, we hypothesized that distinct clinically-relevant contact sites for delivering an HVLA-SM will produce significant differences in paraspinal muscle spindle response.

2. Methods

2.1. Overview

A mechanical device (Fig. 1) was used to apply simulated HVLA-SMs to the lumbar spine of deeply anesthetized cats while recording sensory activity from individual muscle spindles in lumbar muscles attached to the L_6 vertebra (cats have 7 lumbar vertebrae). An HVLA-SM was applied at each of 4 contact sites: lamina, mammillary process and spinous process of the target L_6 vertebra and spinous process of the adjacent L_7 vertebra. Two types of responses from muscle spindles were assessed: 1) their responses during the HVLA-SM thrust and 2) their responses to slow changes in vertebral position during simulated spinal movement using ramp and hold displacement of the L_6 vertebra before and after the HVLA-SM.

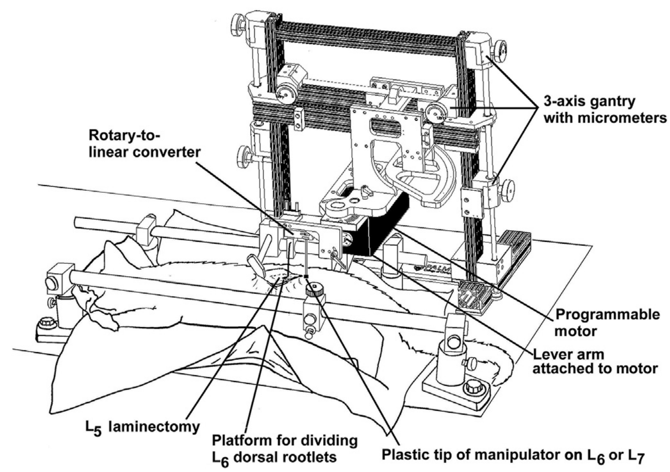

Fig. 1. Schematic of the preparation for delivering spinal manipulation to the lumbar spine while recording sensory input from the dorsal roots. The motor was controlled by a programmable, electronic feedback system (not shown). Tissues of the vertebrae receiving a spinal manipulation (L_6 and L_7) remained intact including the skin. Rotary motion of the motor's lever arm was converted to linear motion by a custom built converter. The converter in turn was attached to a rod terminating in a small, circular, plastic tip (5 mm diameter) placed on the intact skin at the contact site. Micrometers attached to the 3-axis gantry allowed positioning of the manipulator's tip to within 0.05 mm of an intended contact site.

2.2. Preparation

Experiments were performed on 16 deeply anesthetized cats weighing between 2.6 and 4.1 kg [mean 3.6 (SD 0.4)]. All experiments were approved by the Institutional Animal Care and Use Committee. All surgical and electrophysiological procedures have been previously established and described in detail (Pickar, 1999; Sung et al., 2005; Reed et al., 2013). Deep anesthesia was maintained with Nembutal [35 mg/kg intravenous]. A laminectomy was performed at L_5 exposing the L_6 dorsal rootlets for electrophysiological recordings.

2.3. Muscle spindle activity

Finely teased filaments from the L_6 dorsal rootlets were placed on a monopolar electrode until the recording contained a single unit that responded only to mechanical pressure applied directly to muscles of the low back and not the pelvis or leg. Standard neurophysiological techniques were used at the experiment's end to confirm the afferent innervated a muscle spindle (see Appendix).

2.4. HVLA-SM and contact sites

The mechanical device used to load the spine (see Fig. 1) was identical to that used in previous investigations (Reed et al., 2013; Cao et al., 2013; Reed et al., 2014). The simulated HVLA-SM was applied in a posterior-anterior direction as commonly delivered to a patient in a prone position. Thrust duration was 100 ms, similar to that used clinically and the peak thrust force was 21.3 N, scaled from a human to a cat. See Appendix for additional details.

Contact sites for applying the HVLA-SM (see Fig. 2) were based upon those used in clinical practice: a lumbar vertebra's lamina, spinous process, or mammillary process (Peterson and Bergmann,