World Spine Care

3rd Botswana Spine Conference | Gaborone, Botswana, May 7-8, 2018

Scientific Base for Chiropractic Treatments

Christopher J. Colloca, DC, PhD

CEO, Neuromechanical Innovations

Chairman, International Spine Research (INSPIRE) Foundation

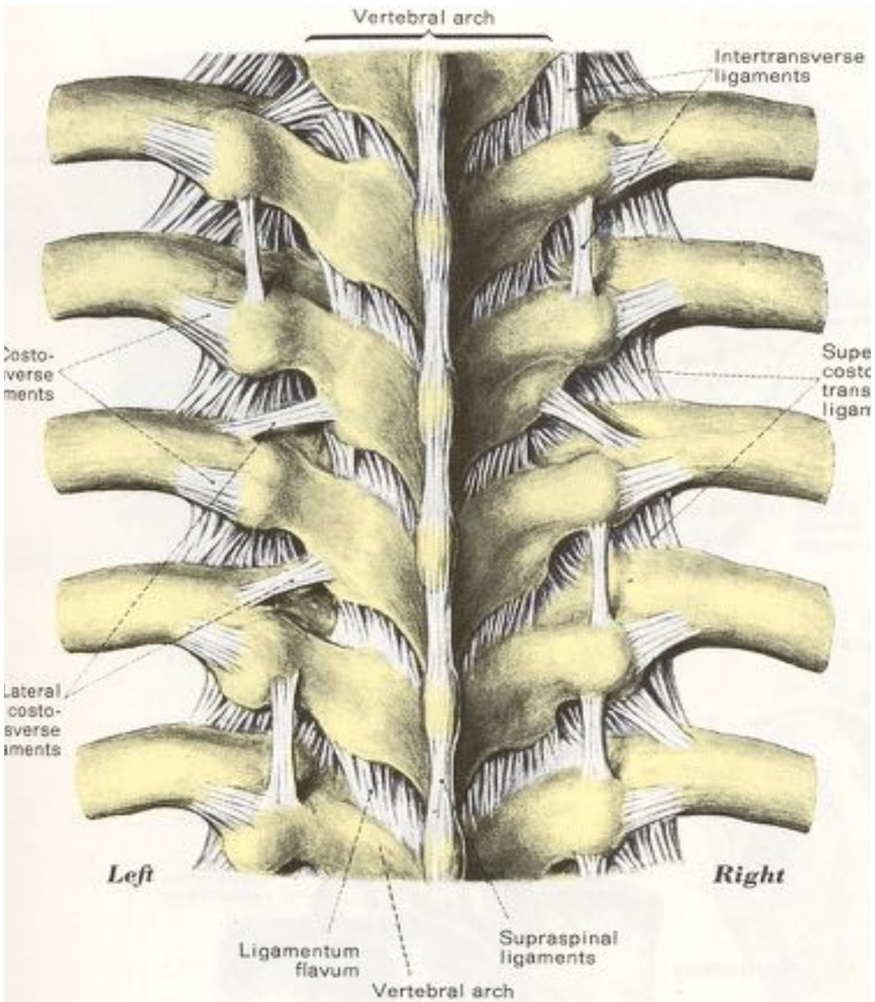
Chandler, Arizona, USA

Neuromechanical INNOVATIONS

INSPIRE International Spine Research Foundation

Spinal Ligaments …

& Joint Stability

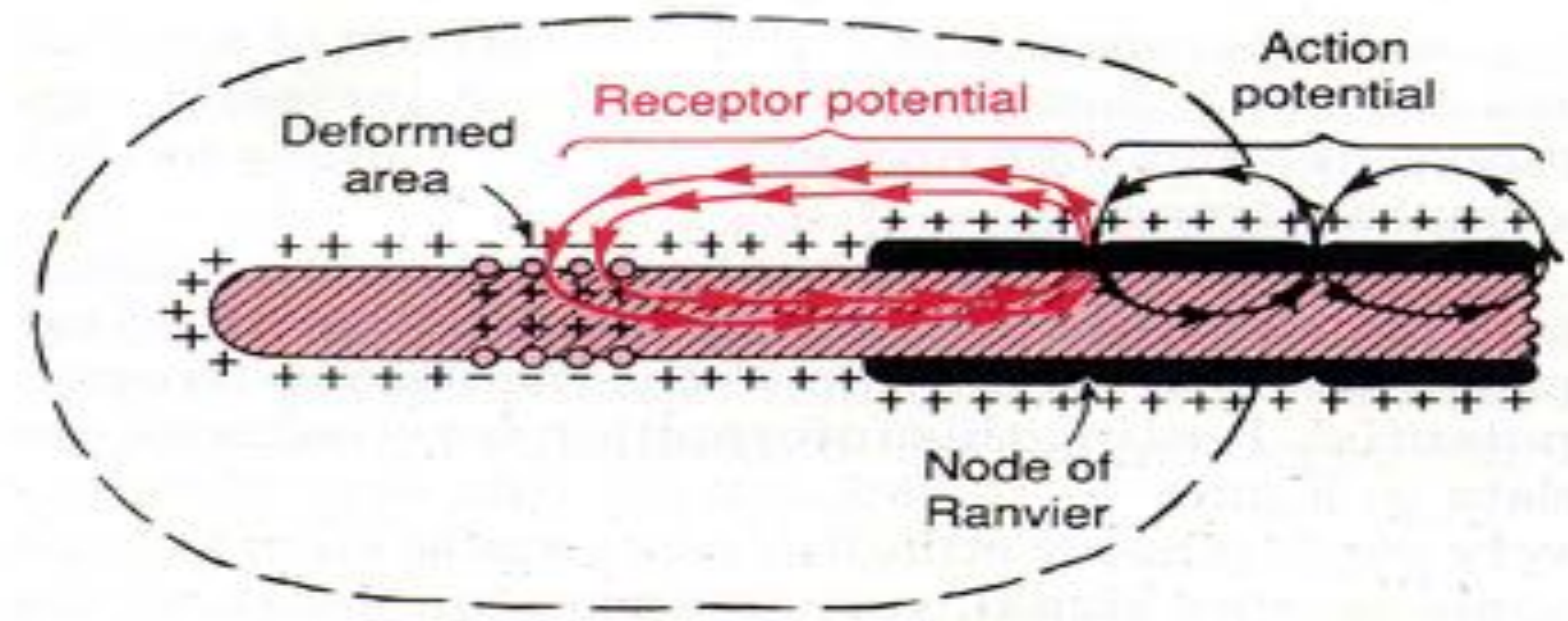


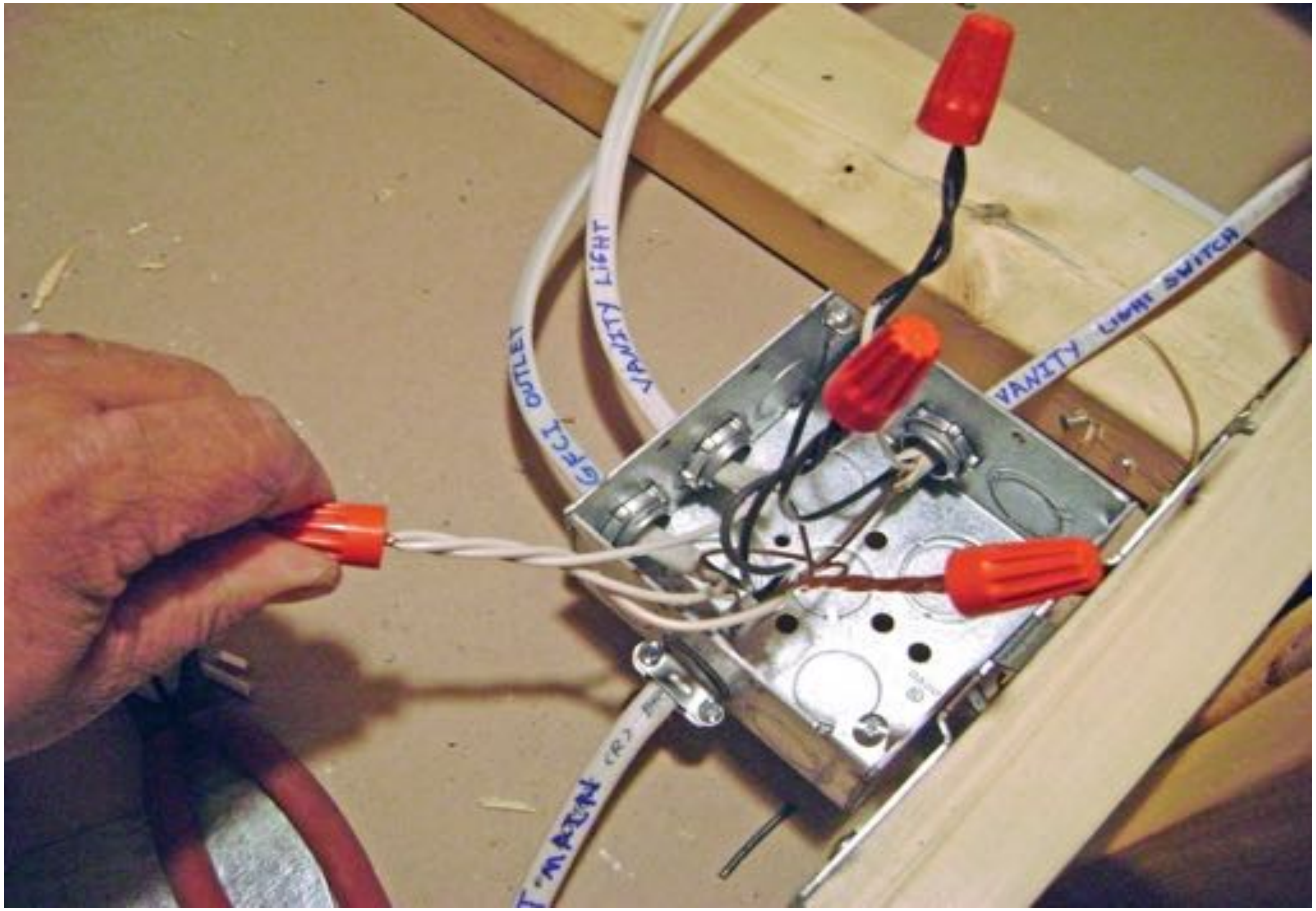
- ALL
- PLL
- Ligamentum Flavum
- Interspinous Ligament
- Supraspinous Ligament
- Facet Capsular Ligament

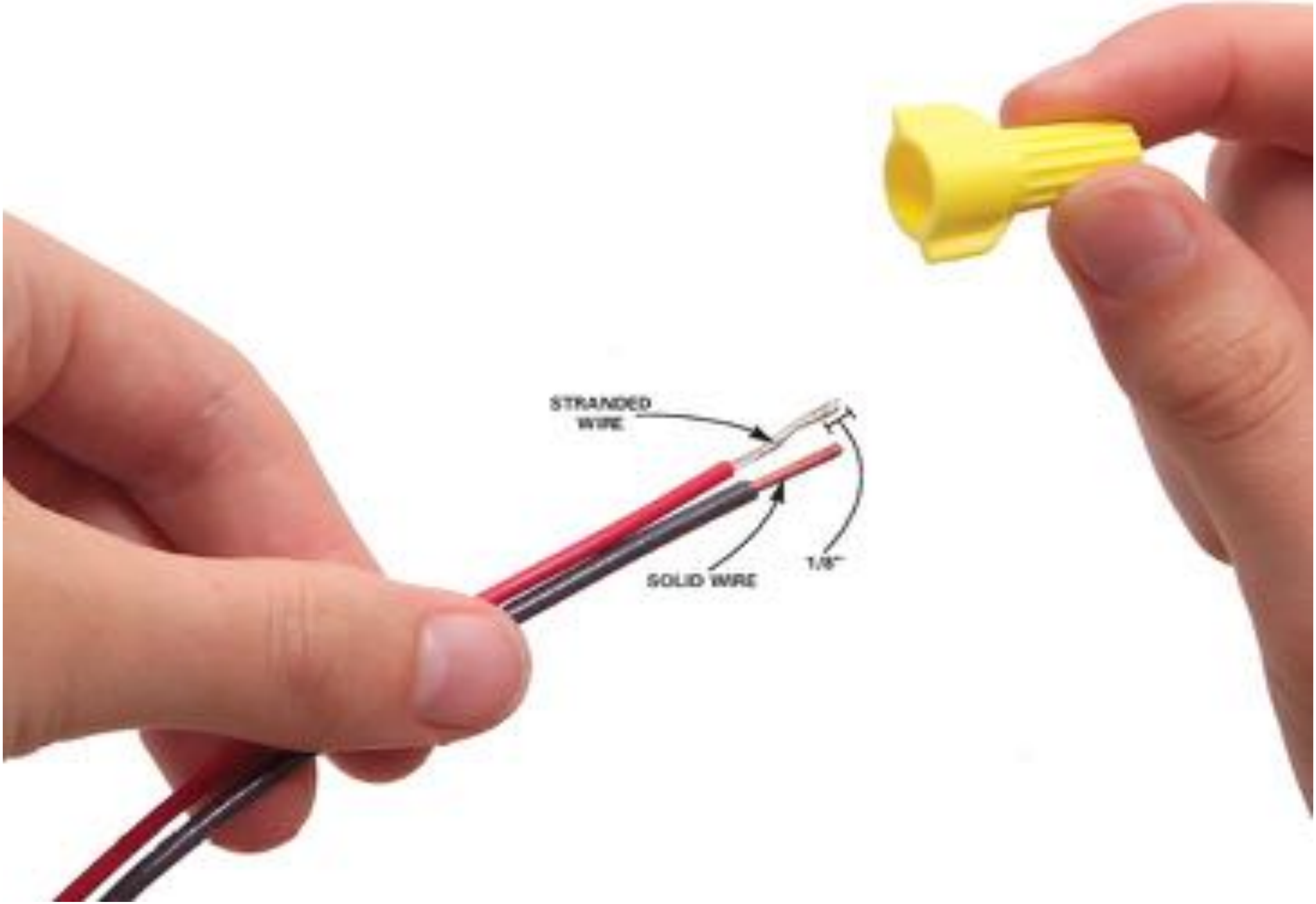
Jiang H, Russell G, Raso J, Moreau MJ, Hill DL, Bagnall KM.
The Nature and Distribution of the Innervation of Human Supraspinal & Interspinal Ligaments.
Spine 1995; 20:869-76.

"Although ligament has been traditionally considered only as a mechanical structure, there is increasing evidence to suggest that ligaments are innervated and can participate in active neuromuscular reflexes."

Mechanoreceptors Transform mechanical force, or displacement, into action potentials

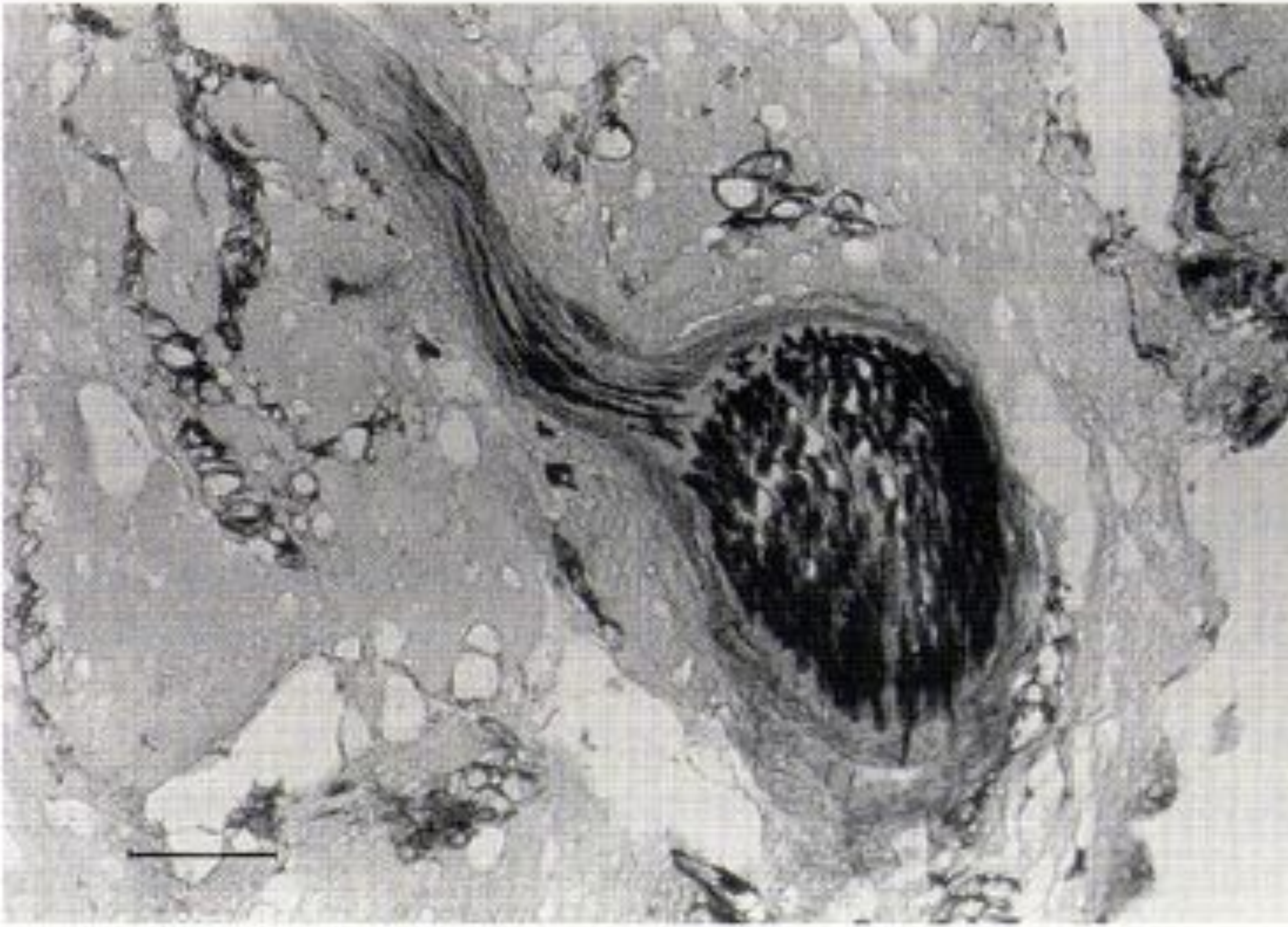



GFCI OUTLET
VANITY LIGHT
VANITY LIGHT SWITCH


STRANDED WIRE
SOLID WIRE
1/8"

McLain RF. Mechanoreceptor Endings in Human Cervical Facet Joints. Spine 1994; 19:495-501.

- **Dissected 21 human cervical facet capsules from 3 normal subjects.**
- **Identified type I: 11**
  type II: 20 **
  type III: 5
  type IV: Numerous



McLain RF. Mechanoreceptor Endings in Human Cervical Facet Joints. Spine 1994; 19:495-501.

"The presence of mechanoreceptive and nociceptive nerve endings in cervical facet capsules <u>proves</u> that these tissues are monitored by the CNS and implies that neural input from the facets is important to proprioception and pain sensation in the cervical spine."

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Journal of Orthopaedic Research 19 (2001) 593–596

Journal of Orthopaedic Research

www.elsevier.nl/locate/orthres

Immunohistochemical demonstration of nerve fibers in the synovial fold of the human cervical facet joint

Satoshi Inami [a,*], Takashi Shiga [b], Akihito Tsujino [a], Takeshi Yabuki [c], Nobuo Okado [b], Naoyuki Ochiai [a]

Abstract

The role of the intra-articular synovial fold as a source of facet joint pain is unclear, because the nature of nociceptive innervation in lumbar synovial folds is controversial, and there have been no such studies in cervical synovial folds. The present study aimed to demonstrate the presence of nerve fibers including nociceptive fibers in synovial folds of human cervical facet joints using immunohistochemistry. Synovial folds of cervical facet joints removed from patients undergoing cervical spine laminoplasty were analyzed immunohistochemically using antibodies to protein gene product 9.5, β III-tubulin, substance P and calcitonin gene-related peptide. Many nerve fibers immunoreactive for protein gene product 9.5 and β III-tubulin were demonstrated both around blood vessels and as free fibers in the stroma of the synovial fold. Also, immunostaining showed the presence of free nerve fibers immunoreactive for substance P and calcitonin gene-related peptide in the stroma. The presence of putative nociceptive fibers in cervical synovial folds supports a possible role for these structures as a source of cervical facet joint pain.

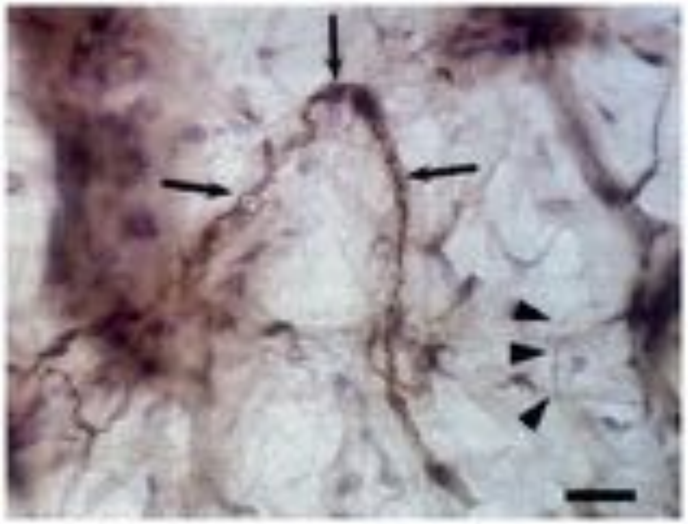


Fig. 1. PGP 9.5-immunoreactive nerves in the synovial fold of the cervical facet joint from the donor aged 60 years. Thin bundles (arrows) and individual fibers are seen. Fine nerve fibers with varicosity are found running freely in the tissue stroma (arrowheads). Hematoxyline counterstaining. Bar = 50 μm.

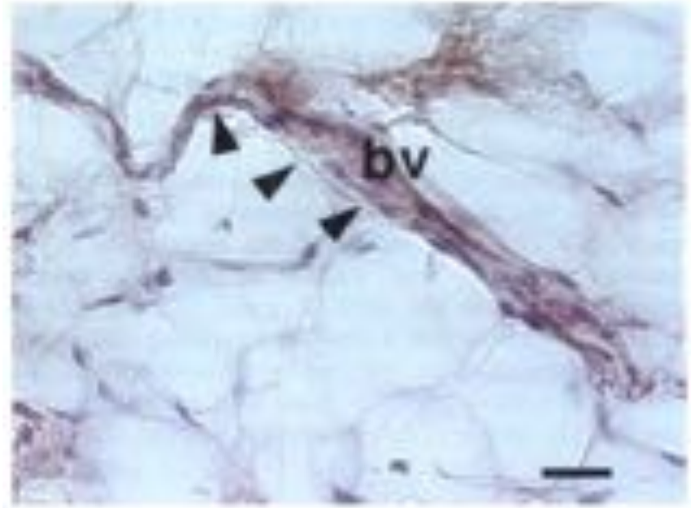


Fig. 2. Perivascular nerve (arrowheads) stained with β III-tubulin in the synovial fold of the cervical facet joint from the donor aged 58 years. bv – blood vessel. Hematoxylin counterstaining. Bar = 50 μm.

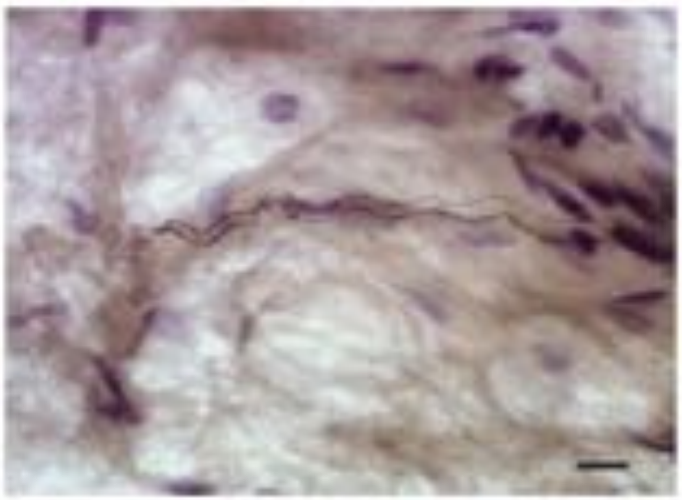


Fig. 3. SP-immunoreactive nerve fibers running parallel with repeated varicosities in the synovial fold of the cervical facet joint from the donor aged 60 years. Hematoxylin counterstaining. Bar = 20 μm.

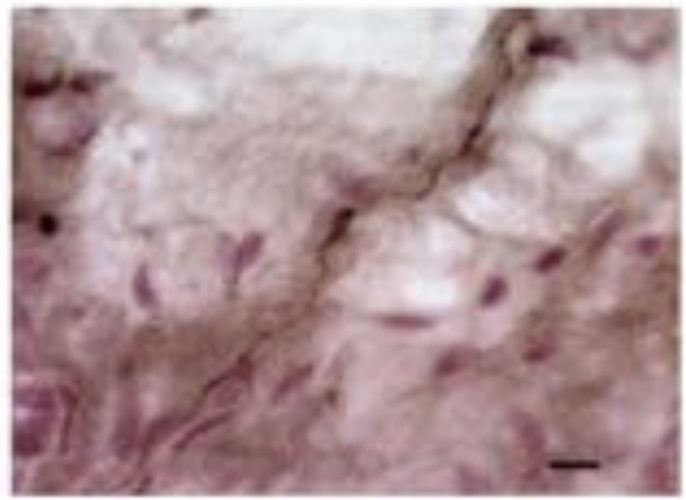
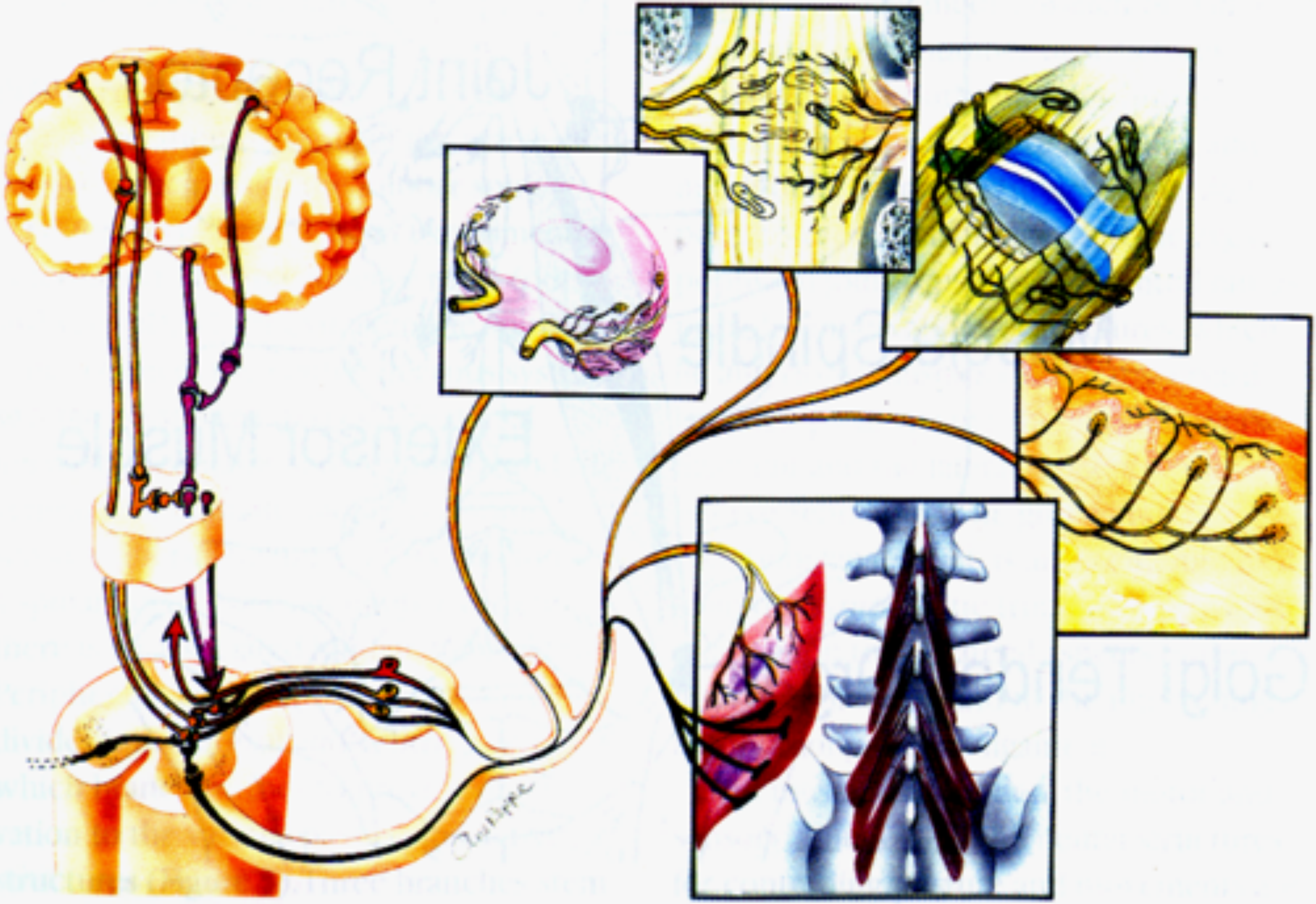
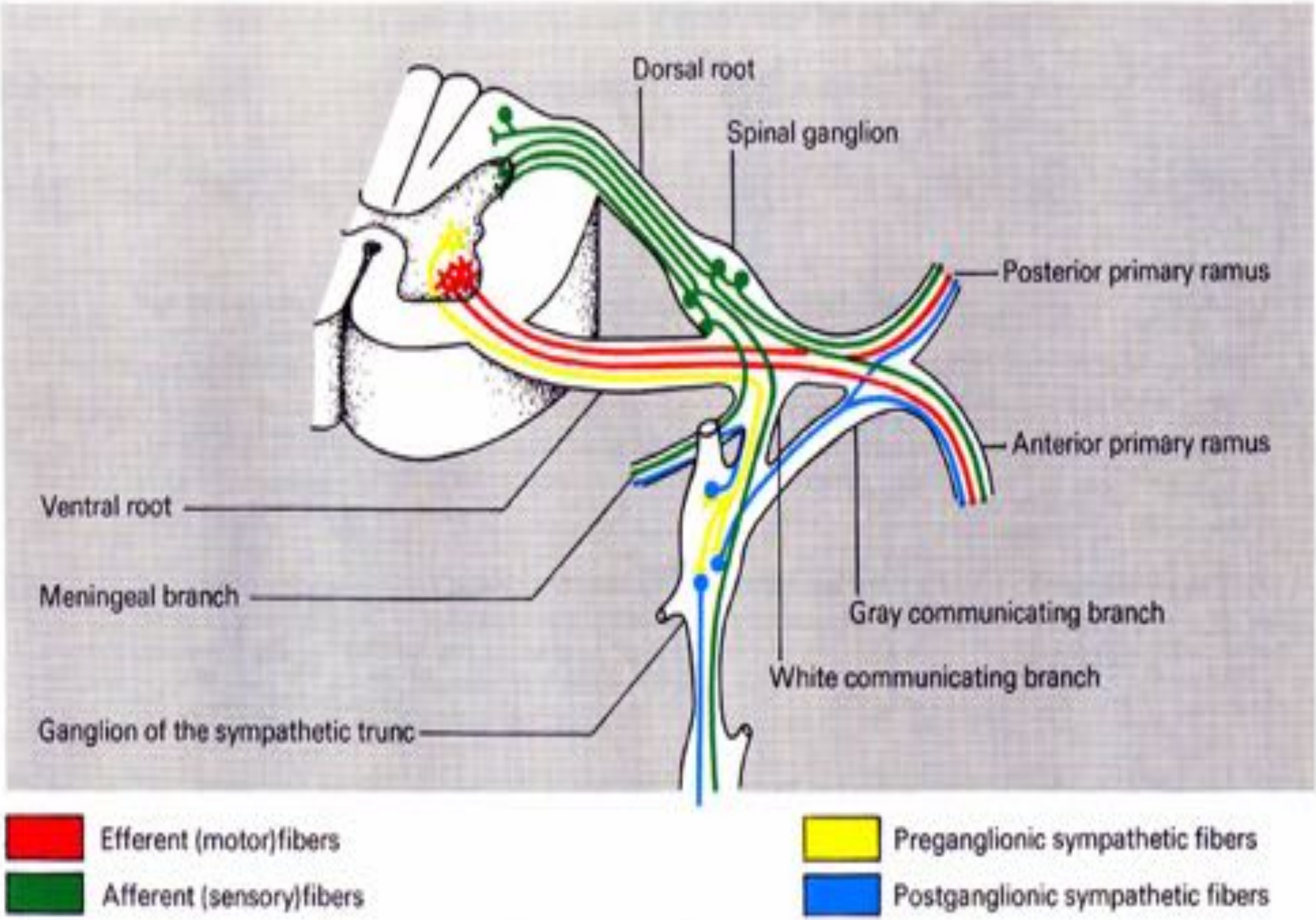


Fig. 4. CGRP-immunoreactive nerve fiber with varicose appearance in the same synovial fold as shown in Fig. 3. Hematoxylin counterstaining. Bar = 20 μm.

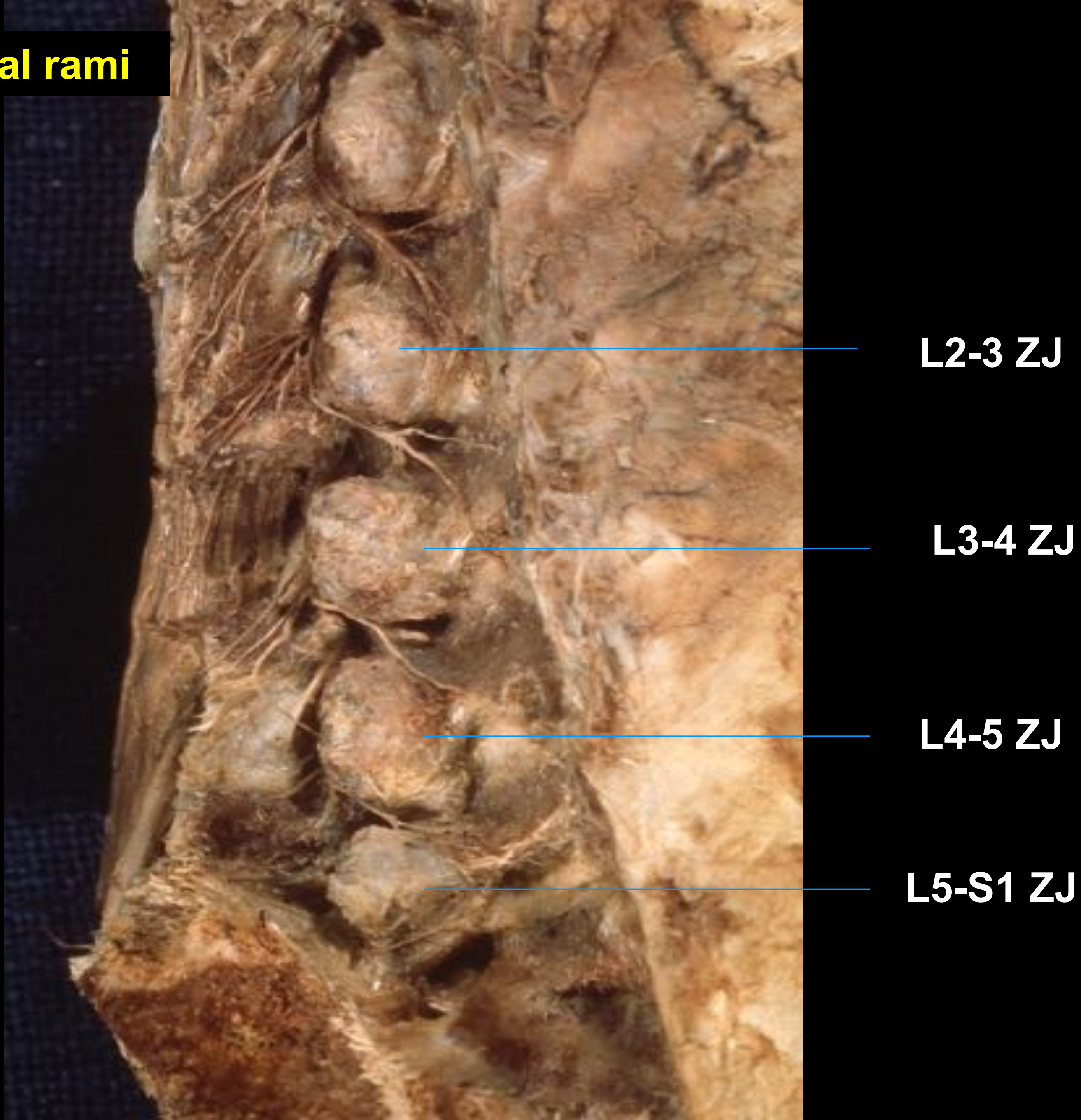
2007 International Whiplash Trauma




Dorsal root
Spinal ganglion
Posterior primary ramus
Anterior primary ramus
Ventral root
Meningeal branch
Gray communicating branch
White communicating branch
Ganglion of the sympathetic trunc
Efferent (motor)fibers
Afferent (sensory)fibers
Preganglionic sympathetic fibers
Postganglionic sympathetic fibers

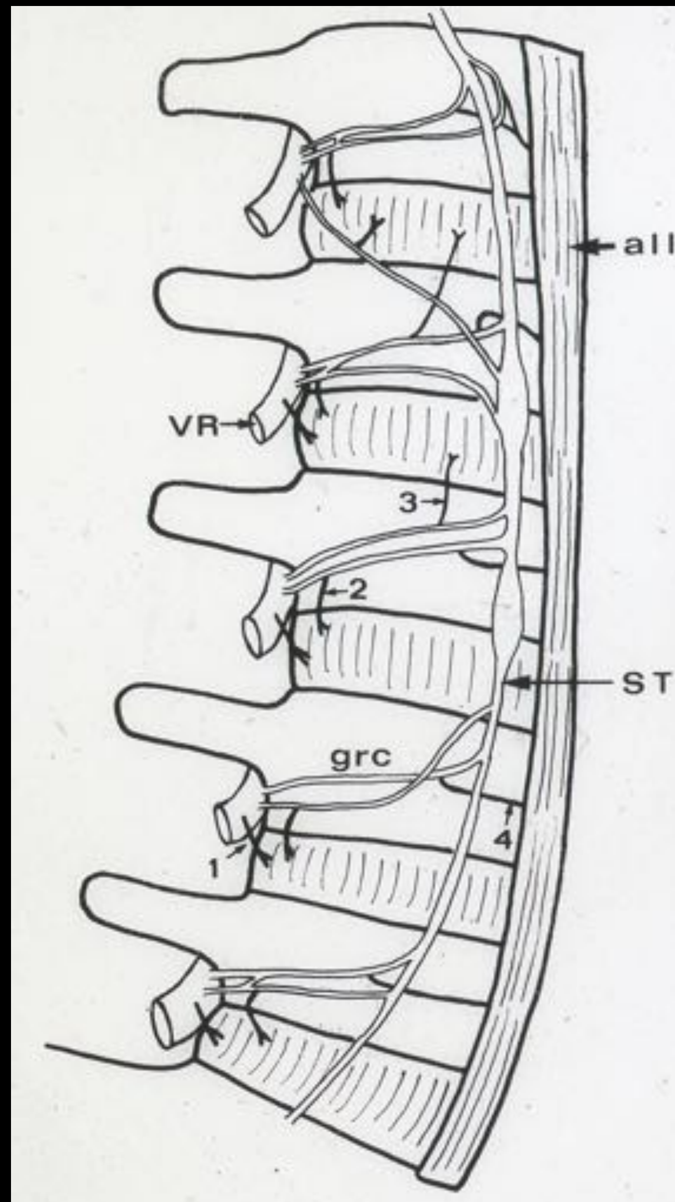
LEFT Lumbar dorsal rami

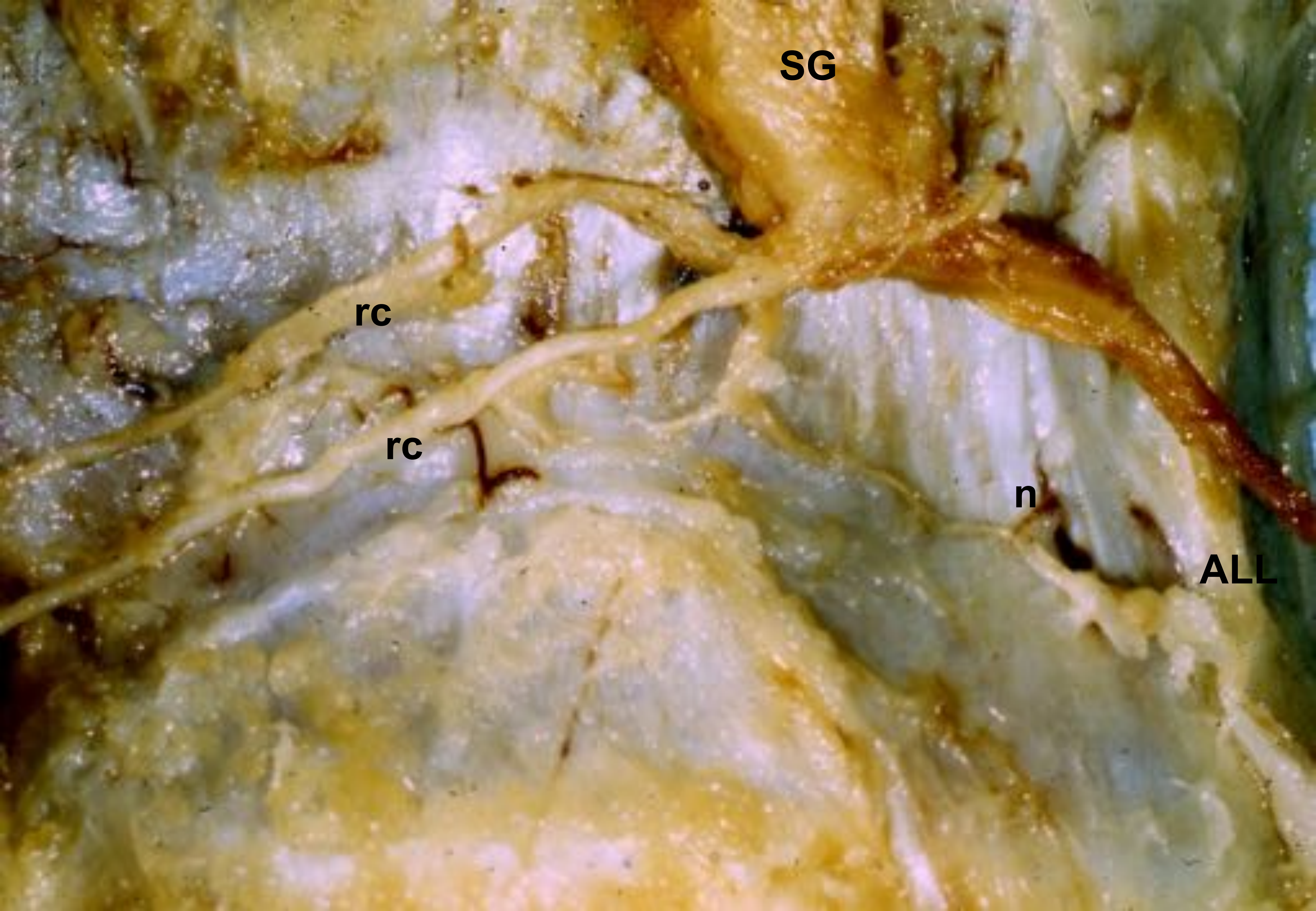
LEFT Lumbar dorsal rami



LEFT Lumbar dorsal rami

Grey rami communicantes, ventral rami, and sympathetic trunk

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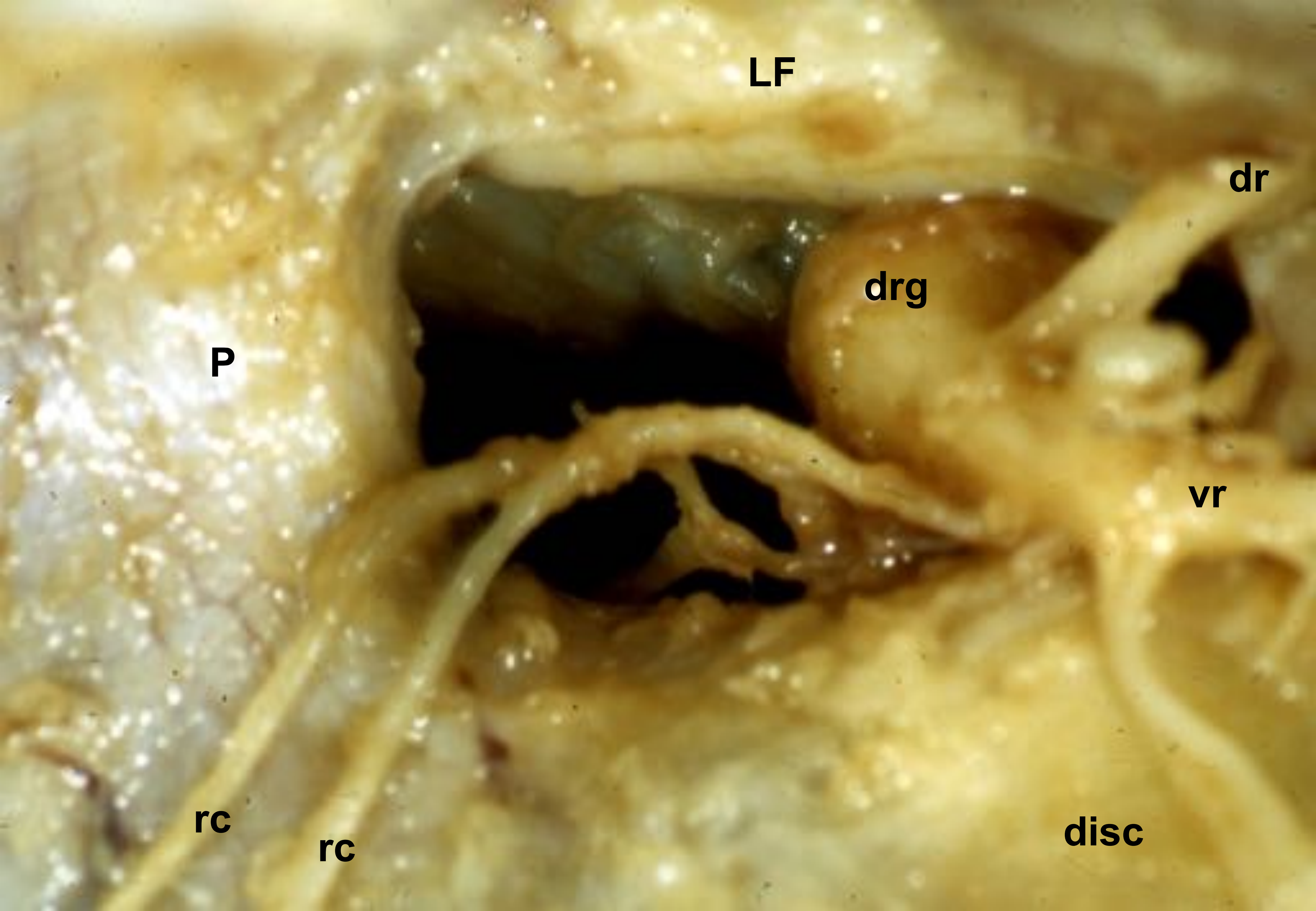
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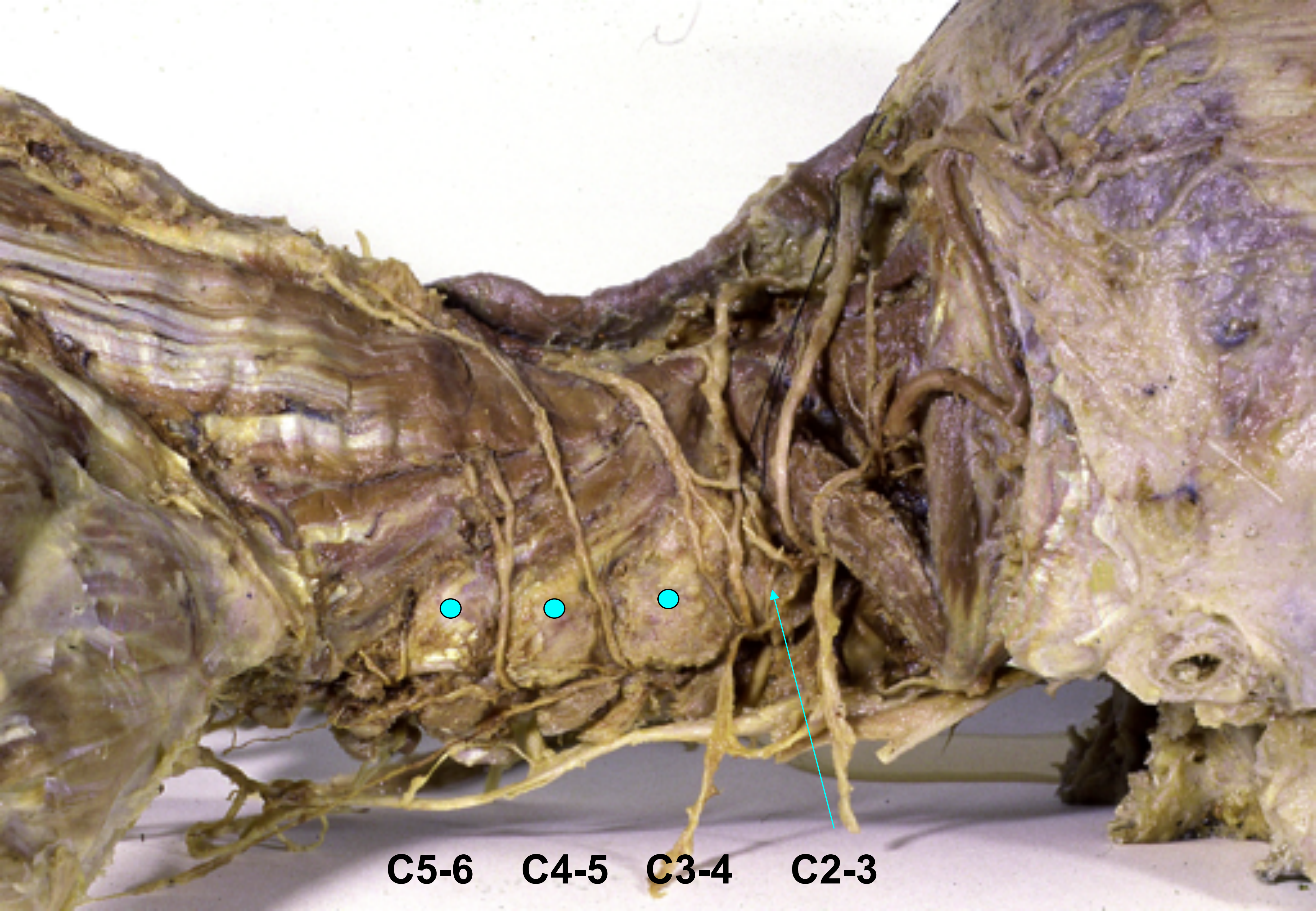
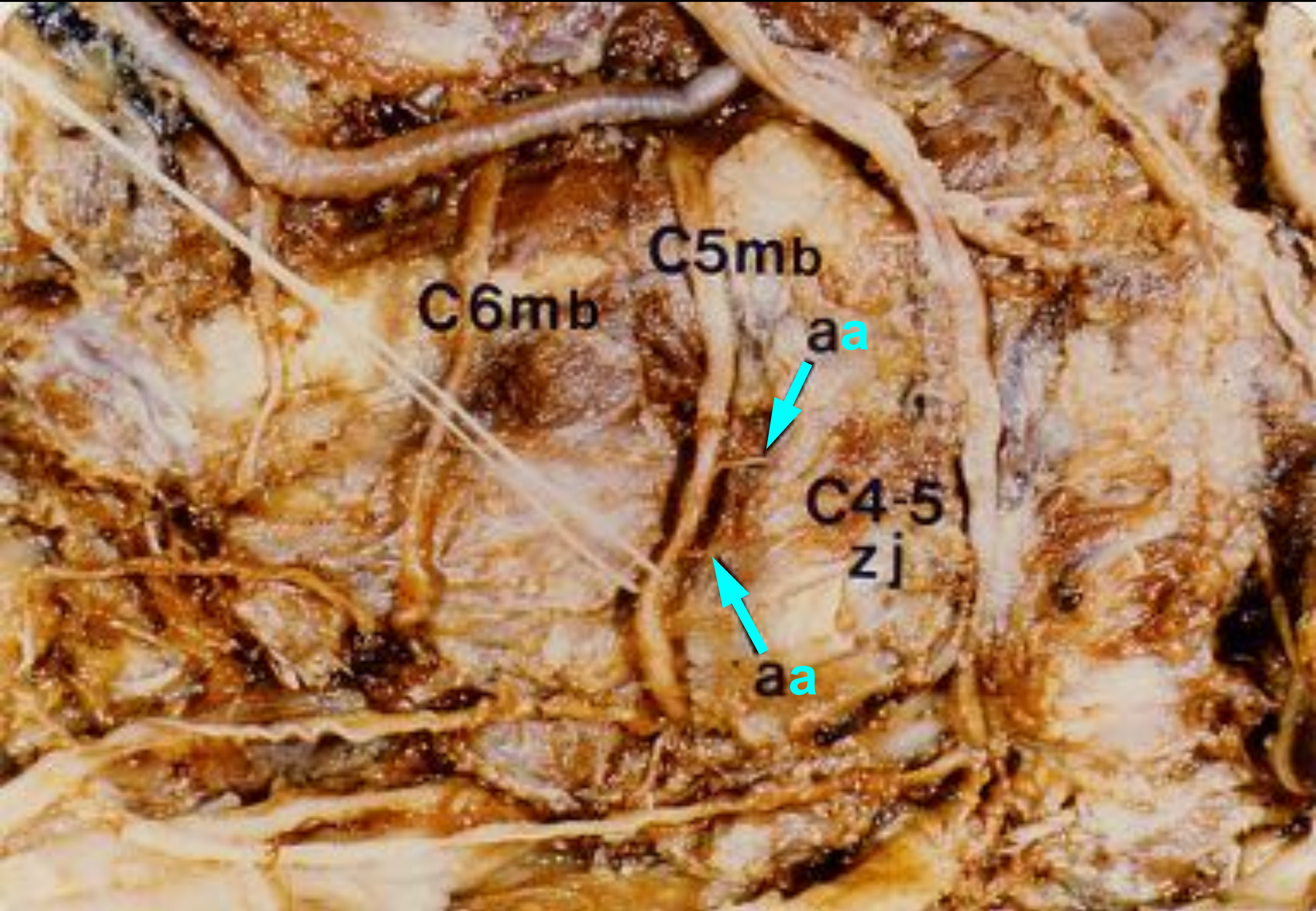
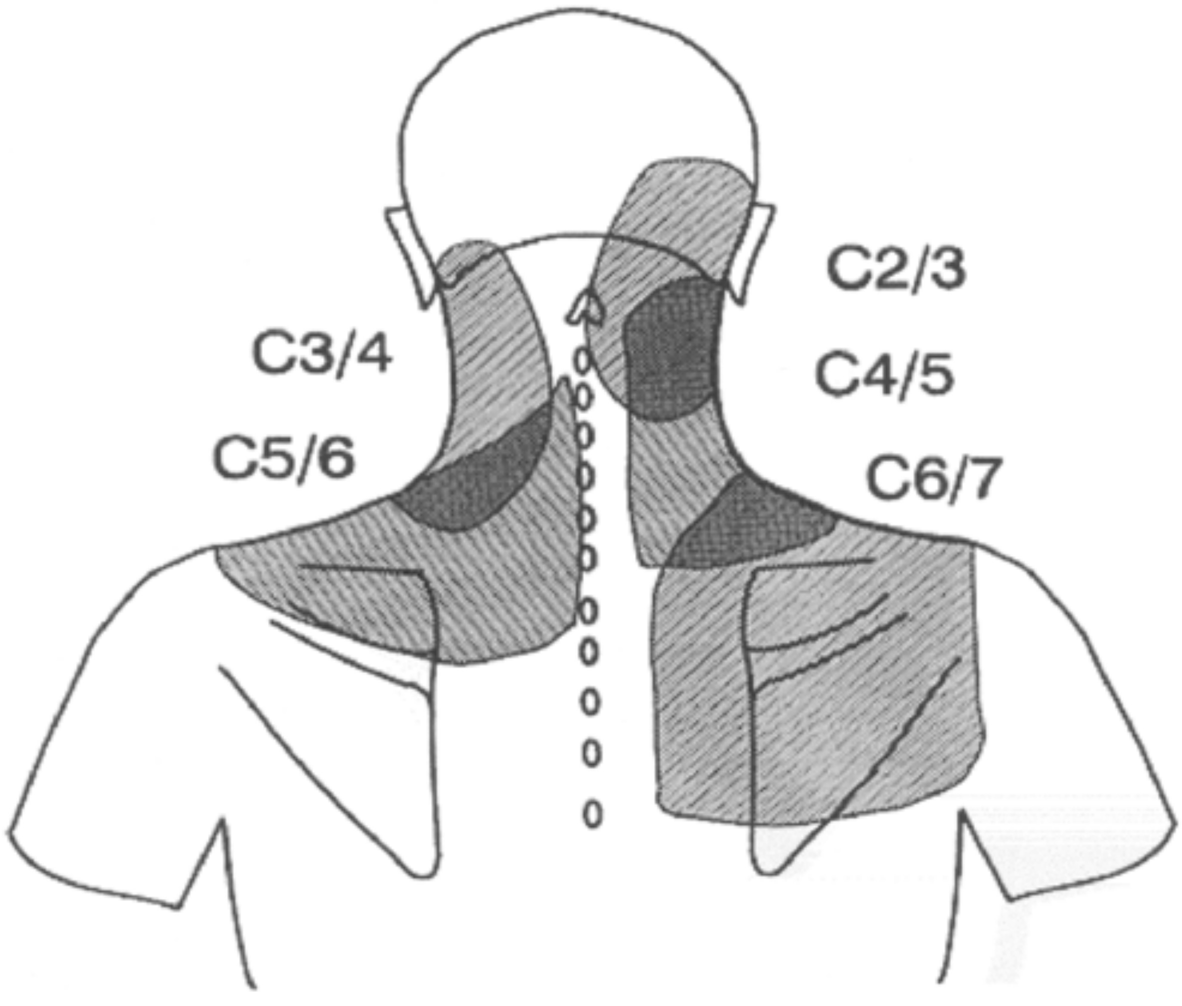

C5-6
C4-5
C3-4
C2-3


C5mb
C6mb
aa
C4-5
zj
aa

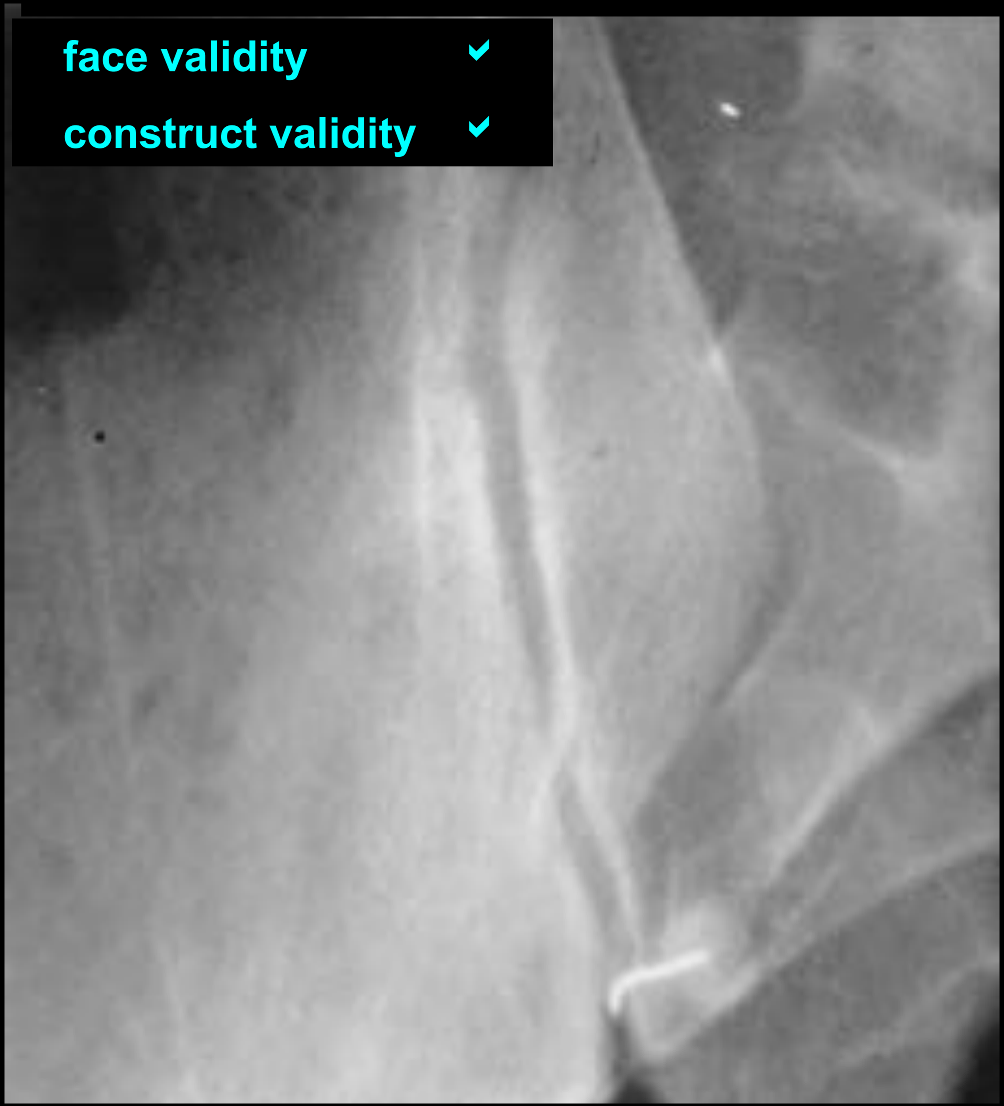
Cervical Zygapophyseal Joint Pain Referral Patterns



SACROILIAC JOINT BLOCKS

face validity ✓

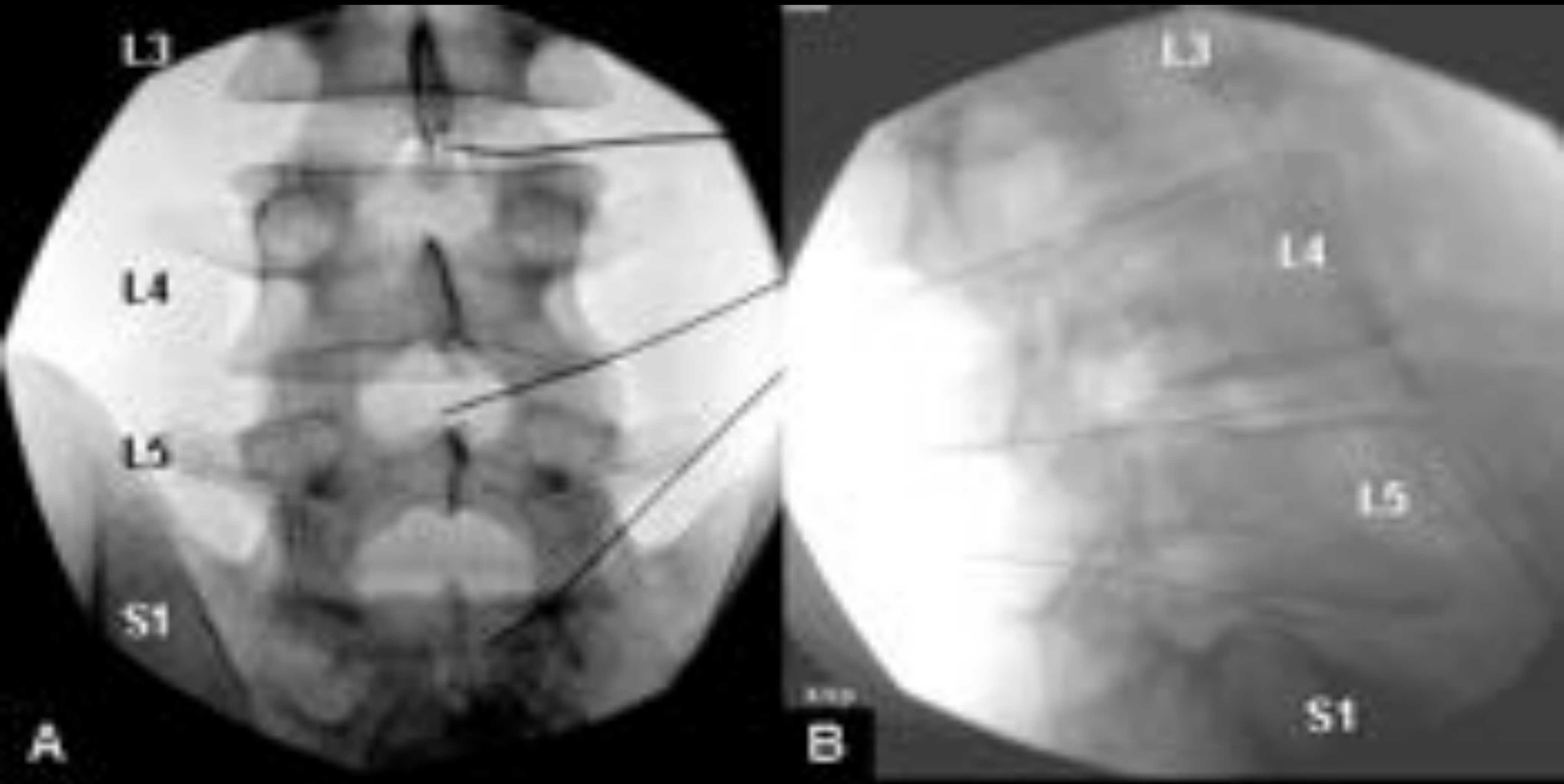
construct validity ✓



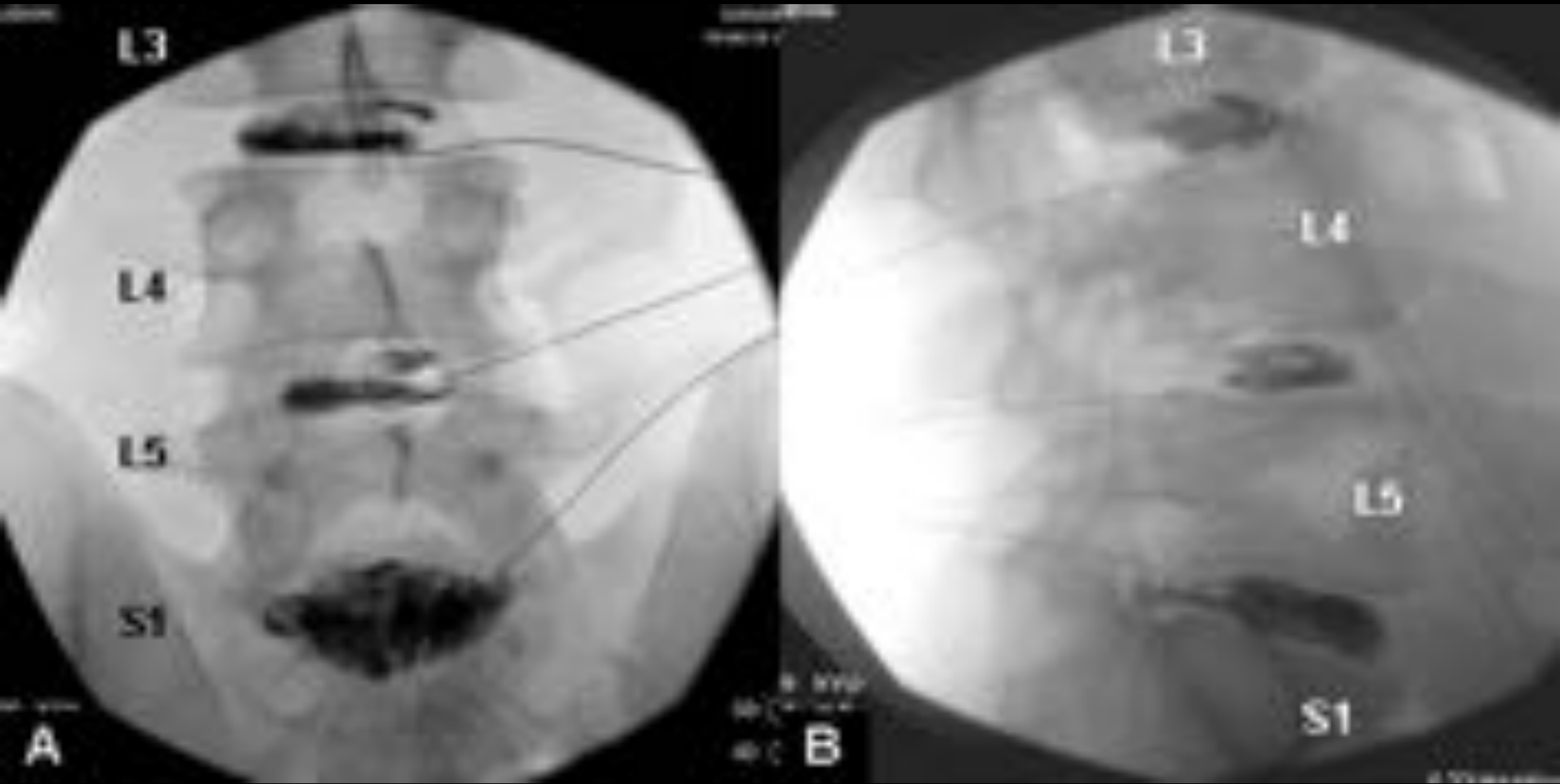
Schwarzer AC, Aprill CN, Bogduk N. The sacroiliac joint in chronic low back pain. Spine 1995; 20:31-37.

Maigne JY, Aivaliklis A, Pfefer F. Results of sacroiliac joint double block and value of sacroiliac pain provocation tests in 54 patients with low back pain. Spine 1996; 21:1889-1892.

DISC STIMULATION (discography)

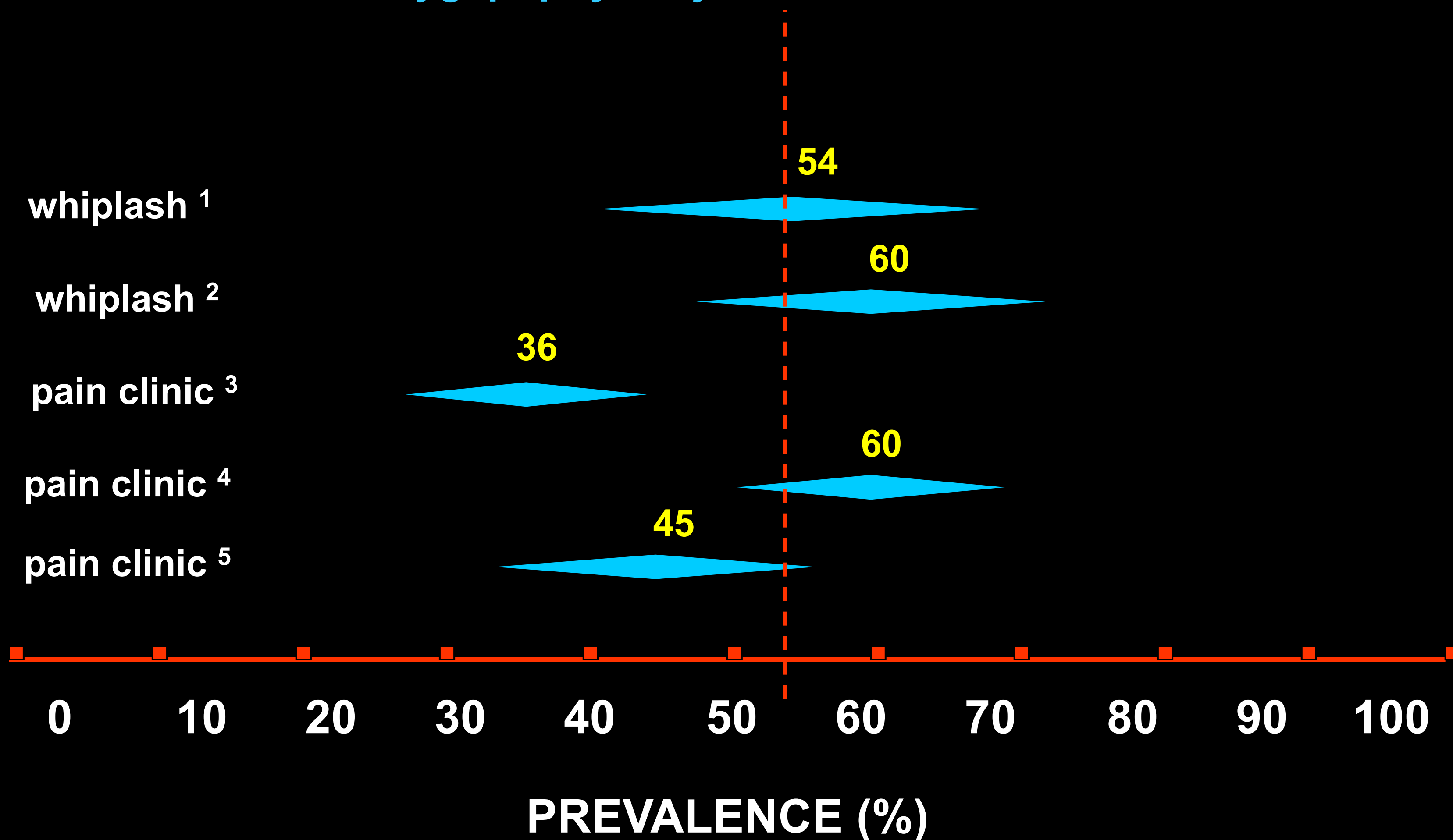


DISC STIMULATION (discography)



prevalence CERVICAL

Zygapophysial joints



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ScienceDirect
Journal of Electromyography and Kinesiology 16 (2006) 549–567
Journal of Electromyography and Kinesiology
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2006 ISEK Congress Keynote Lecture

Sensory – Motor control of ligaments and associated neuromuscular disorders

M. Solomonow *

Musculoskeletal Disorders Research Laboratory, Bioengineering Section, Department of Orthopaedic Surgery, University of Colorado at Denver and Health Sciences Center, 12800 East 19th Avenue, Room 2103, Mailstop 8343, P.O. Box 6511, Aurora, Denver, CO 80045, USA

Abstract

The ligaments were considered, over several centuries, as the major restraints of the joints, keeping the associated bones in position and preventing instability, e.g. their separation from each other and/or mal-alignment. This project, conducted over 25 years, presents the following hypothesis:

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SPECIAL ISSUE:
Spinal Manipulations

GUEST EDITORS:
Christopher J. Colloca
Joel G. Pickar
Malik Slosberg

OFFICIAL JOURNAL OF
THE INTERNATIONAL SOCIETY OF
ELECTROPHYSIOLOGY AND KINESIOLOGY
AND THE JAPANESE SOCIETY OF
ELECTROPHYSIOLOGICAL KINESIOLOGY

Eur Spine J (2006) 15: 668–676
DOI 10.1007/s00586-005-0925-3

ORIGINAL ARTICLE

Manohar M. Panjabi

A hypothesis of chronic back pain: ligament subfailure injuries lead to muscle control dysfunction

The hypothesis

The hypothesis consists of the following sequential steps:

1. Single trauma or cumulative microtrauma causes *subfailure injury* of the spinal ligaments and injury to the mechanoreceptors embedded in the ligaments.
2. When the injured spine performs a task or it is challenged by an external load, the transducer signals generated by the mechanoreceptors are corrupted.
3. Neuromuscular control unit has difficulty in interpreting the corrupted transducer signals because there is spatial and temporal mismatch between the normally expected and the corrupted signals received.
4. The muscle response pattern generated by the neuromuscular control unit is corrupted, affecting the spatial and temporal coordination and activation of each spinal muscle.
5. The corrupted muscle response pattern leads to corrupted feedback to the control unit via tendon organs of muscles and injured mechanoreceptors, further corrupting the muscle response pattern.
6. The corrupted muscle response pattern produces high stresses and strains in spinal components leading to further subfailure injury of the spinal ligaments, mechanoreceptors and muscles, and overload of facet joints.
7. The abnormal stresses and strains produce inflammation of spinal tissues, which have abundant supply of nociceptive sensors and neural structures.
8. Consequently, over time, chronic back pain may develop. The *subfailure injury* of the spinal ligament is defined as an injury caused by stretching of the tissue beyond its physiological limit, but less than its failure point [48].

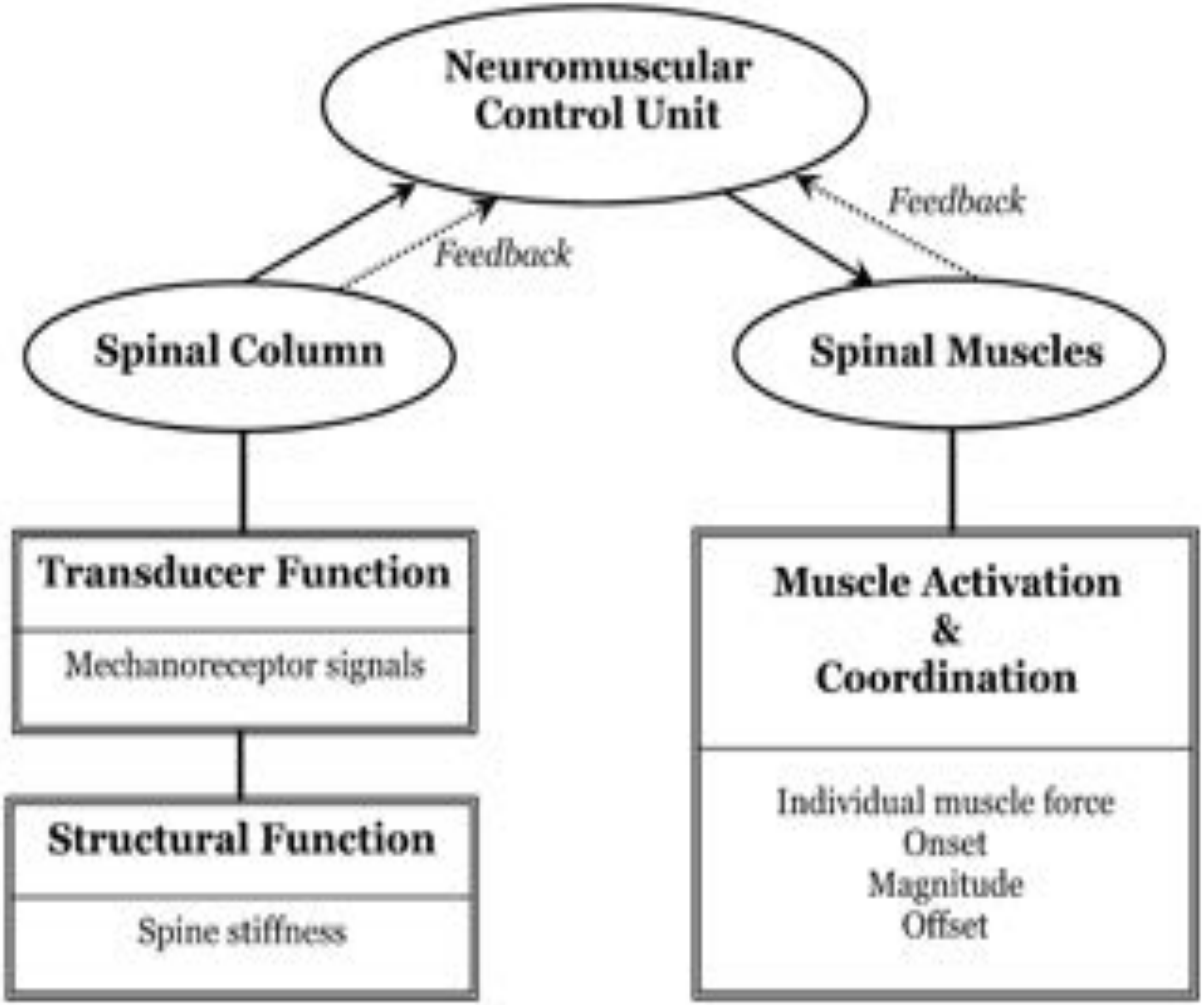
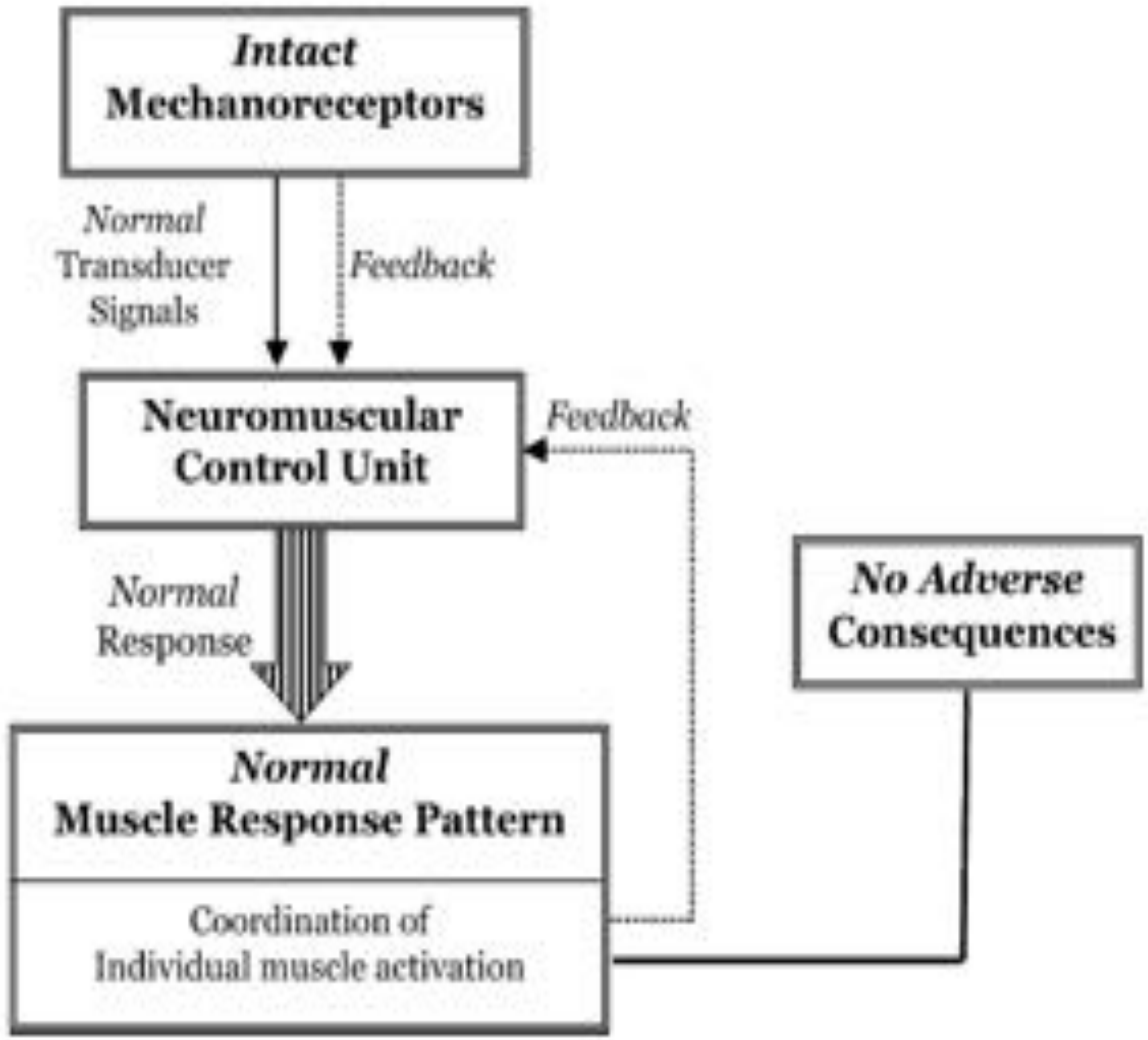


Fig. 1 Spinal stabilizing system. It consists of three subsystems: spinal column, spinal muscles, and neuromuscular control unit. The spinal column has two functions: structural—to provide intrinsic mechanical stability, and transducer—to generate signals describing spinal posture, motions, loads etc. via the mechanoreceptors. The neuromuscular control unit generates muscle response pattern to activate and coordinate the spinal muscles to provide muscle mechanical stability. There is feedback from the spinal muscles and mechanoreceptors to the control unit. (Adapted from Panjabi 1992)

Fig. 2 Normal circumstances. The intact mechanoreceptors send transducer signals to the neuromuscular control unit, which evaluates the transducer signals and sends out muscle response pattern to coordinate the activation of individual spinal muscles. There is feedback from the muscle spindles and golgi tendon organs of the muscles and mechanoreceptors of the ligaments to the neuromuscular control unit. Under normal circumstances, there are no adverse consequences



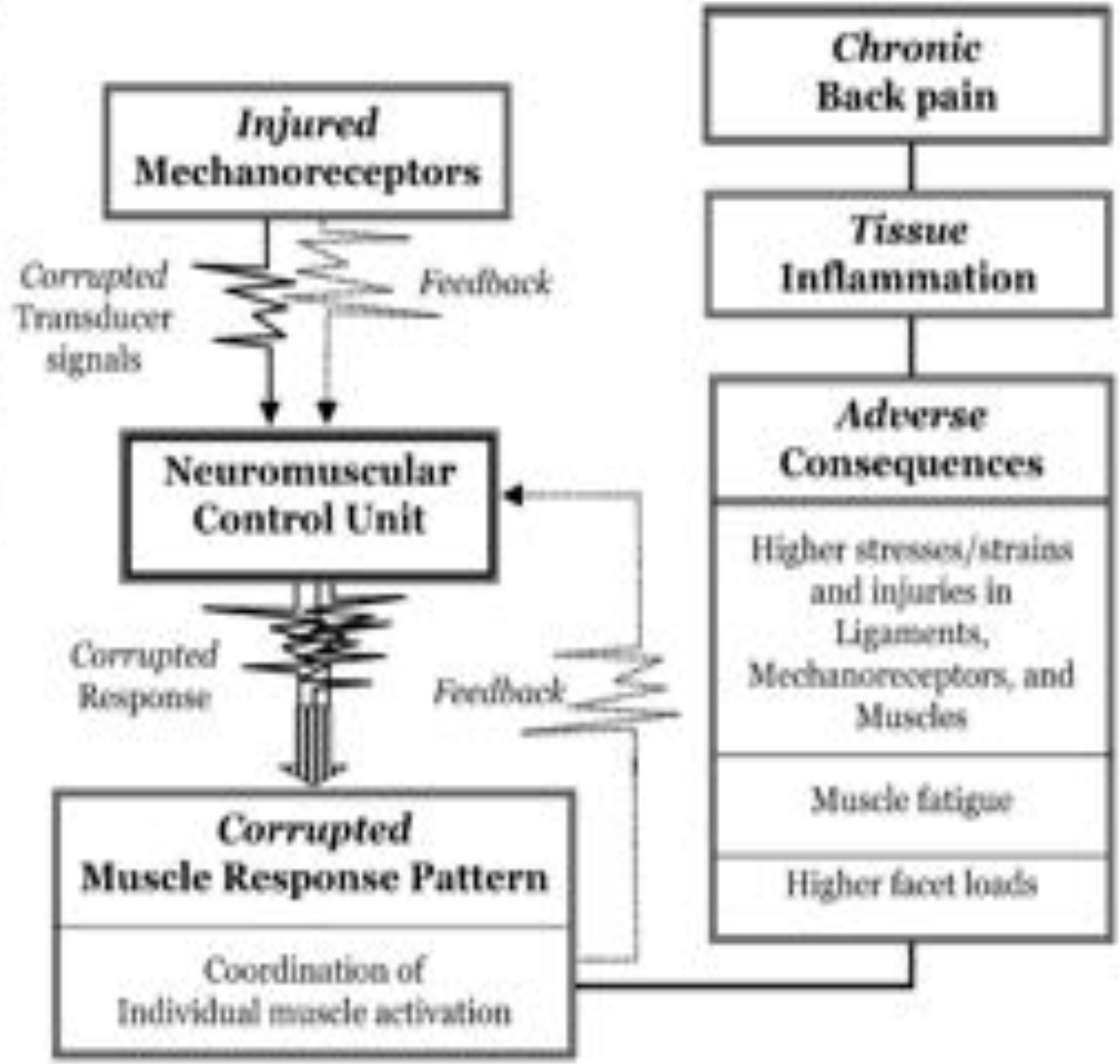


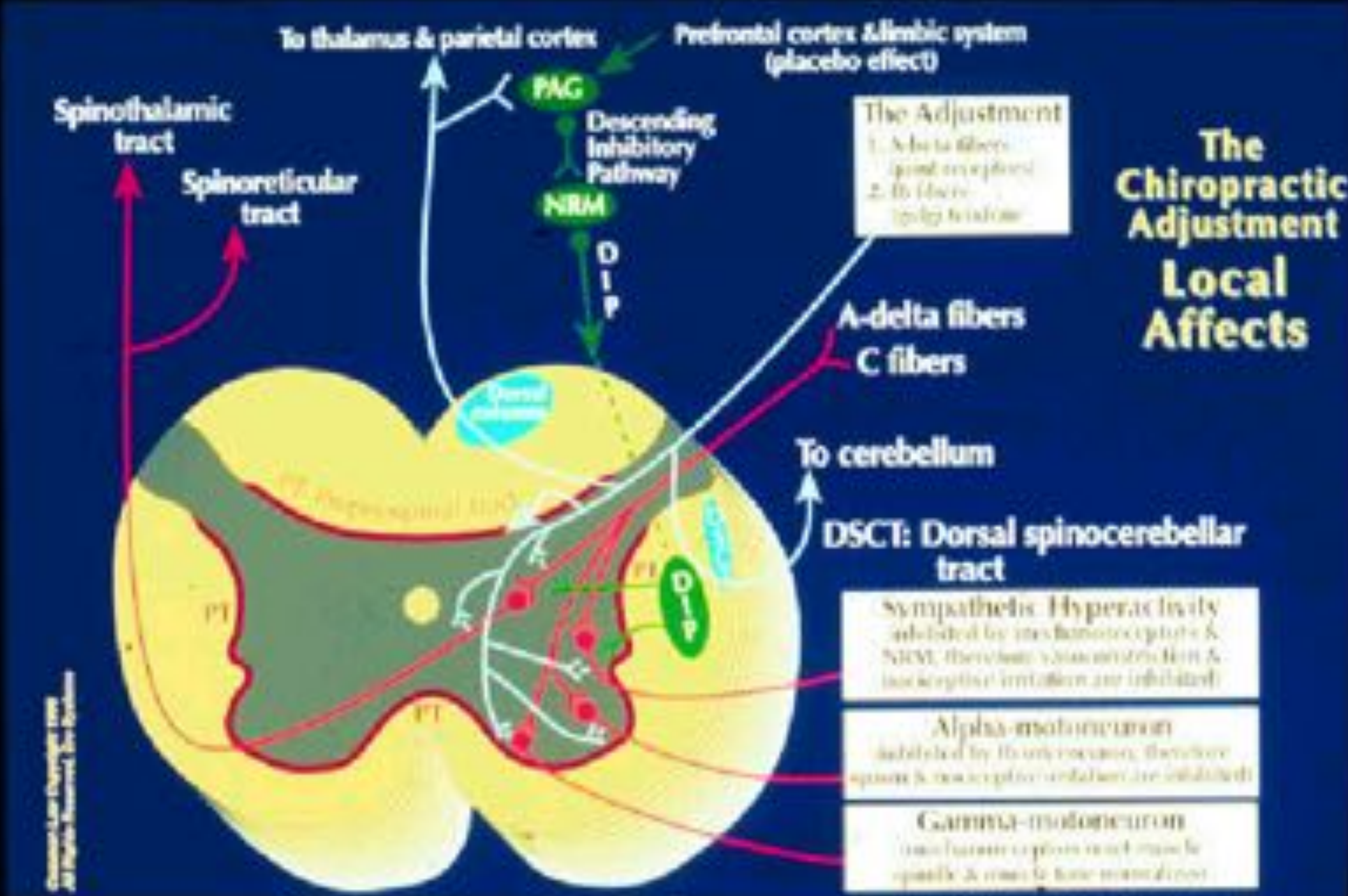
Fig. 3 Subfailure injuries of the ligaments. The injured mechanoreceptors send out *corrupted* transducer signals to the neuromuscular control unit, which finds spatial and temporal mismatch between the expected and received transducer signals, and, as a result, there is muscle system dysfunction and *corrupted* muscle response pattern is generated. Consequently, there are adverse consequences: higher stresses, strains, and even injuries, in the ligaments, mechanoreceptors, and muscles. There may also be muscle fatigue, and excessive facet loads. These abnormal conditions produce neural and ligament inflammation, and over time, chronic back pain

Pain Generation in Lumbar and Cervical Facet Joints

By John M. Cavanaugh, MD, Ying Lu, MS, Chaoyang Chen, MD, and Srinivasu Kallakuri, MS

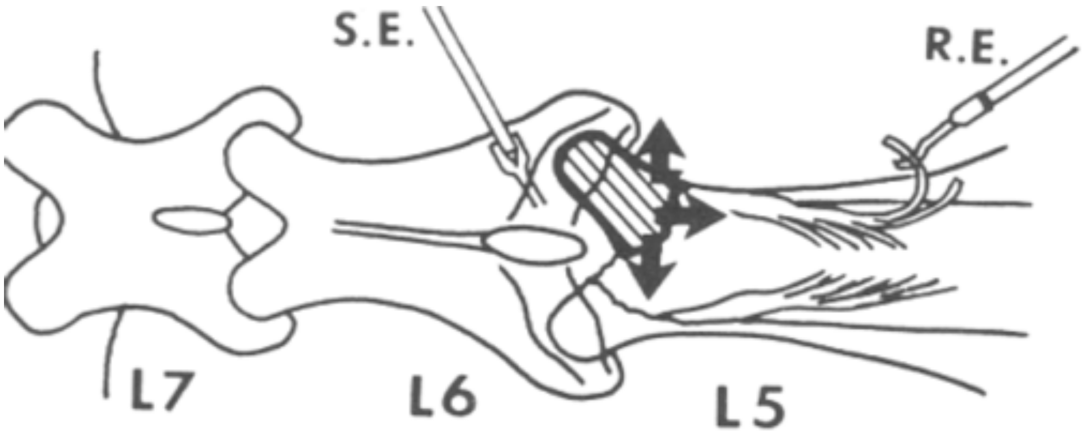
Facet joints are implicated as a major source of neck and low-back pain. Both cervical and lumbar facet syndromes have been described in the medical literature. Biomechanical studies have shown that lumbar and cervical facet-joint capsules can undergo high strains during spine-loading. Neuroanatomic studies have demonstrated free and encapsulated nerve endings in facet joints as well as nerves containing substance P and calcitonin gene-related peptide. Neurophysiologic studies have shown that facet-joint capsules contain low-threshold mechanoreceptors, mechanically sensitive nociceptors, and silent nociceptors. Inflammation leads to decreased thresholds of nerve endings in facet capsules as well as elevated baseline discharge rates. Recent biomechanical studies suggest that rear-end motor-vehicle impacts give rise to excessive deformation of the capsules of lower cervical facet joints. Still unresolved is whether this stretch is sufficient to activate nociceptors in the joint capsule.

To answer this question, recent studies indicate that low stretch levels activate proprioceptors in the facet-joint capsule. Excessive capsule stretch activates nociceptors, leads to prolonged neural afterdischarges, and can cause damage to the capsule and to axons in the capsule. In instances in which a whiplash event is severe enough to injure the joint capsule, facet capsule overstretch is a possible cause of persistent neck pain.

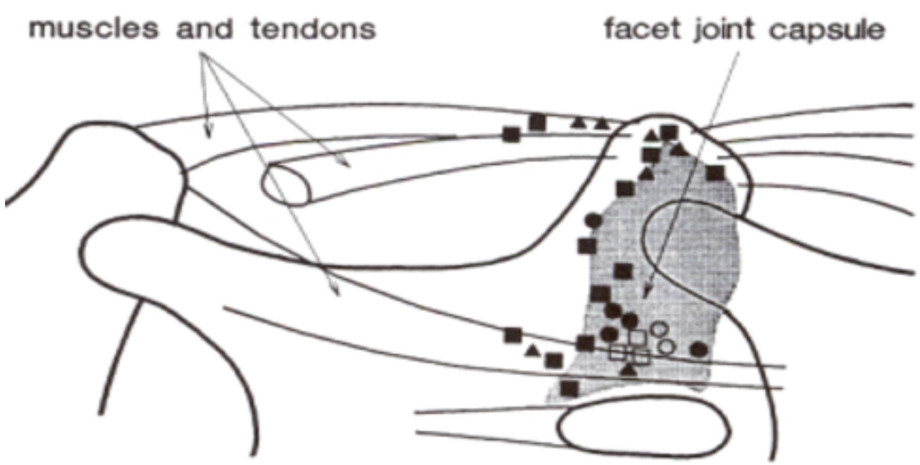


To thalamus & parietal cortex
Prefrontal cortex &limbic system
(placebo effect)
PAG
Descending
Inhibitory
Pathway
NRM
D
I
P
Spinothalamic
tract
Spinoreticular
tract
The Adjustment
The
Chiropractic
Adjustment
Local
Affects
A-delta fibers
C fibers
To cerebellum
DSCT: Dorsal spinocerebellar
tract
D
I
P
Sympathetic Hyperactivity
Alpha-motoneuron
Gamma-motoneuron

Cavanaugh JM, El-Bohy AA, Hardy WN et al. Sensory innervation of soft tissues of the lumbar spine in the rat. J Orthop Res 1989;7:378-88.



Teased nerve roots were monitored as the facet capsule was stretched & electrically stimulated in rats.



Neuromechanical Characterization of In Vivo Lumbar Spinal Manipulation. Part II. Neurophysiological Response

Christopher J. Colloca, DC,[a] Tony S. Keller, PhD,[b] and Robert Gunzburg, MD, PhD[c]

Abstract

Objective: To simultaneously quantify vertebral motions and neuromuscular and spinal nerve root responses to mechanical force, manually assisted, short-lever spinal manipulative thrusts.

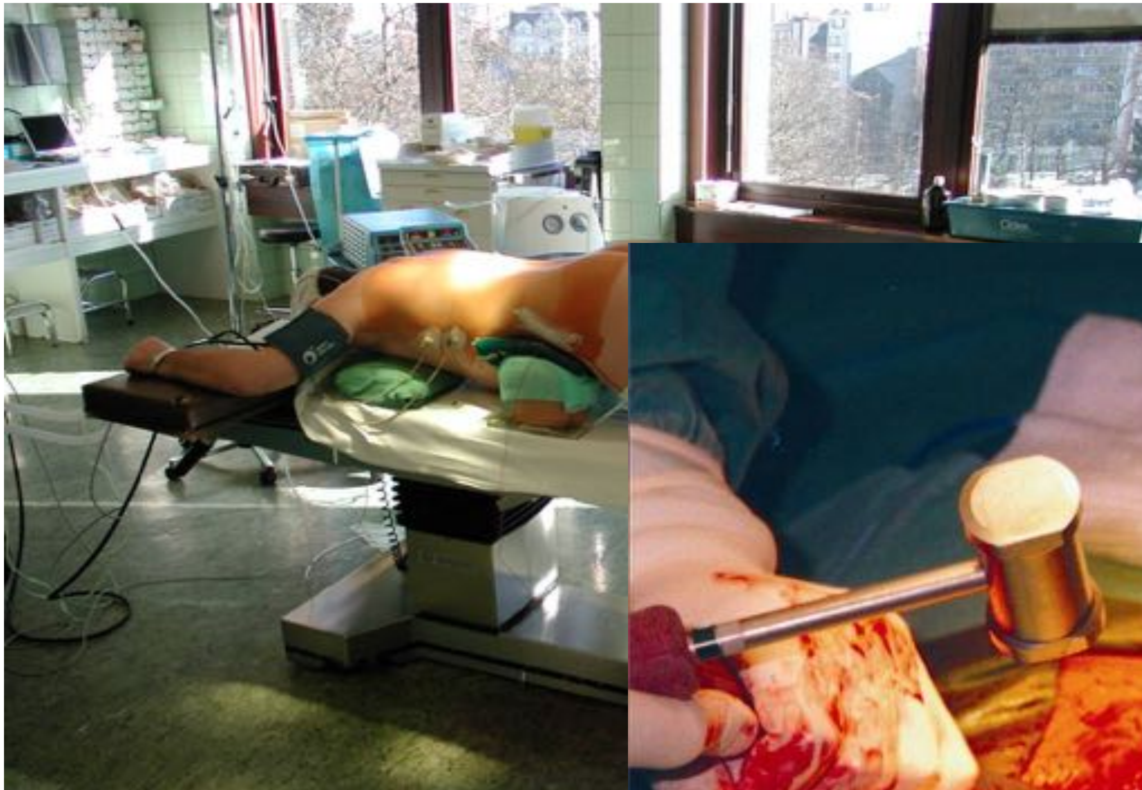
Methods: Four patients underwent lumbar laminarthrectomy to decompress the central spinal canal and neuroforamina, as clinically indicated. Prior to decompression, finely threaded, 1.8-mm diameter intraosseous pins were rigidly fixed to the lumbar spinous process (L1 or L3) using fluoroscopic guidance, and a high-frequency, low-noise, 10-g, triaxial accelerometer was mounted to the pin. Following decompression, 4 needle electromyographic (nEMG) electrodes were inserted into the multifidus musculature adjacent to the pin mount bilaterally, and 2 bipolar platinum electrodes were cradled around the left and right S1 spinal nerve roots. With the spine exposed, spinal manipulative thrusts were delivered internally to the lumbosacral spinous processes and facet joints and externally by contacting the skin overlying the respective spinal landmarks using 2 force settings ($\approx$ 30 N, $<$ 5 milliseconds (ms); $\approx$ 150 N, $<$ 5 ms) and 2 force vectors (posteroanterior and superior; posteroanterior and inferior).

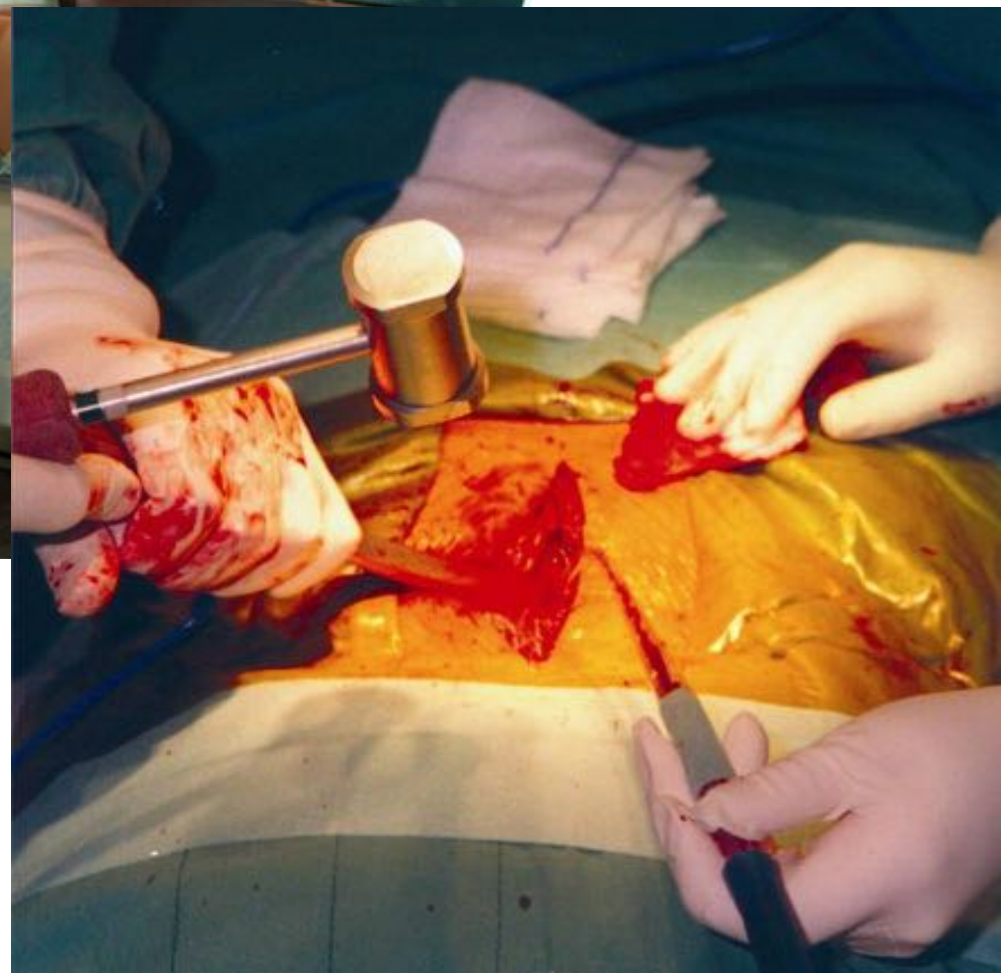
Results: Spinal manipulative thrusts resulted in positive electromyographic (EMG) and compound action potential (CAP) responses that were typically characterized by a single voltage potential change lasting several milliseconds in duration. However, multiple EMG and CAP discharges were observed in numerous cases. The temporal relationship between the initiation of the mechanical thrust and the neurophysiologic response to internal and external spinal manipulative therapy (SMT) thrusts ranged from 2.4 to 18.1 ms and 2.4 to 28.6 ms for EMG and CAP responses, respectively. Neurophysiologic responses varied substantially between patients.

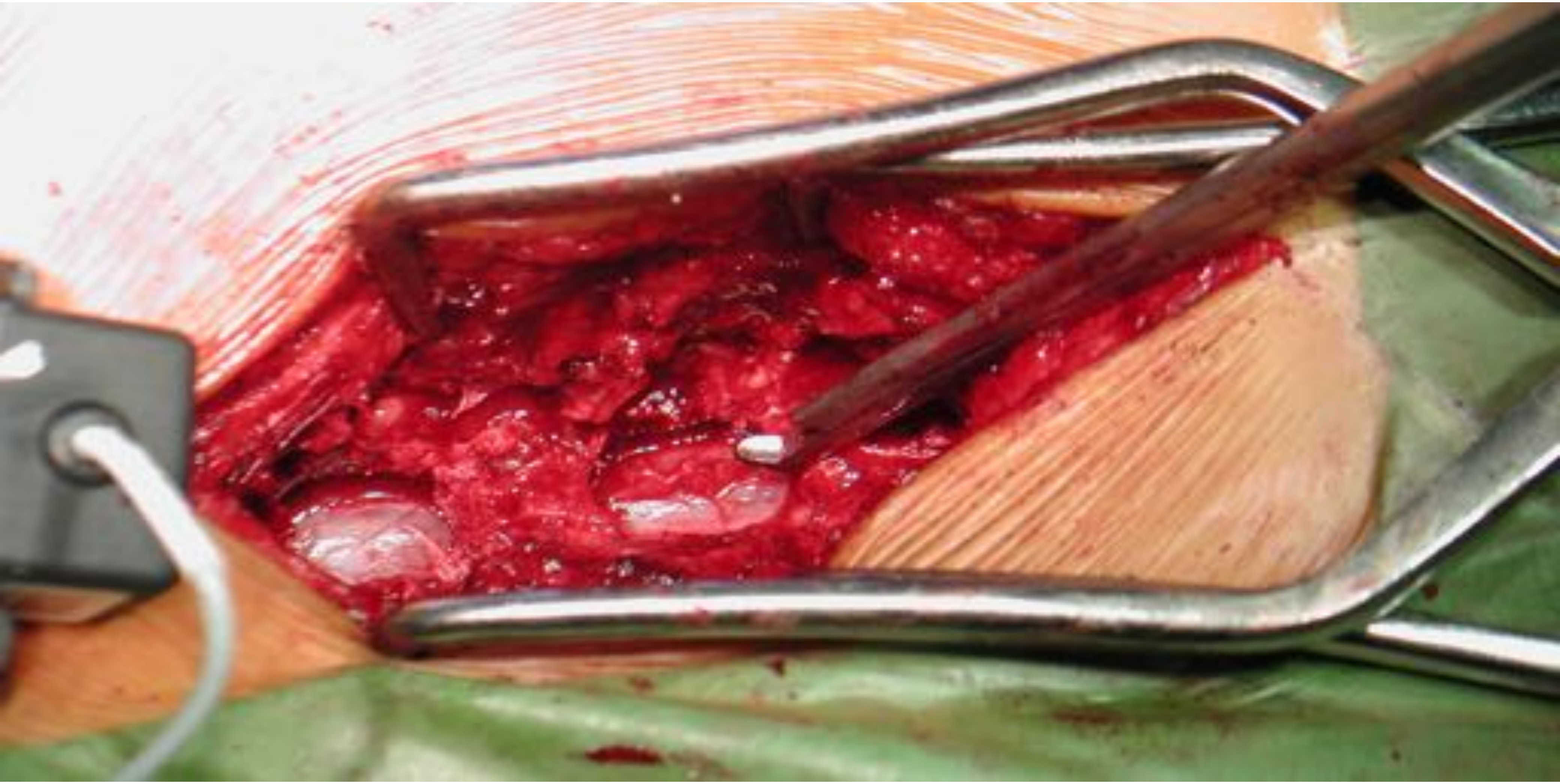
Conclusions: Vertebral motions and resulting spinal nerve root and neuromuscular reflex responses appear to be temporally related to the applied force during SMT. These findings suggest that intersegmental motions produced by spinal manipulation may play a prominent role in eliciting physiologic responses. (J Manipulative Physiol Ther 2003; 26:579-91)

Key Indexing Terms: *Biomechanics; Electromyography; Low Back Pain; Chiropractic Manipulation; Neurophysiology; Sciatica*

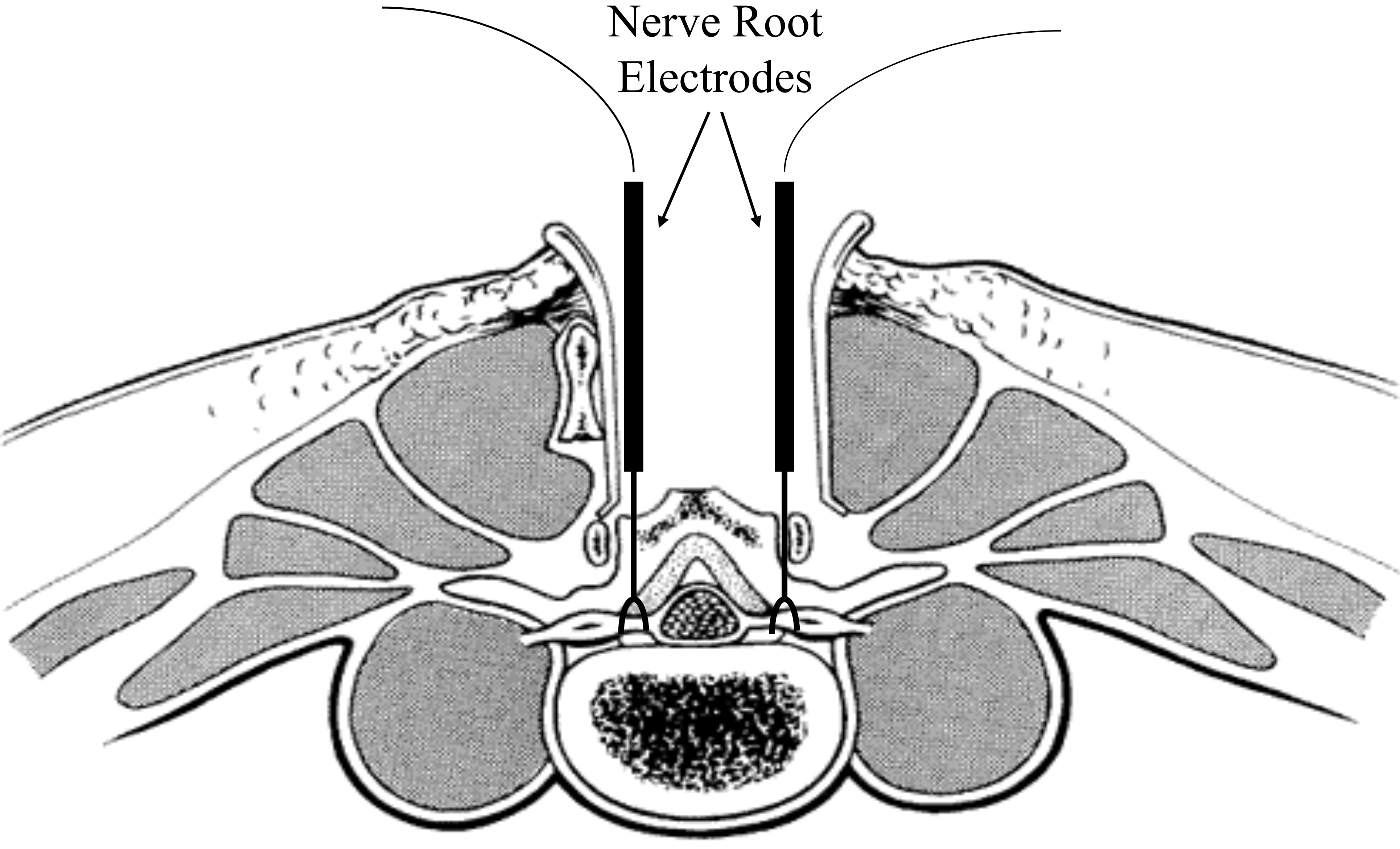
Methods

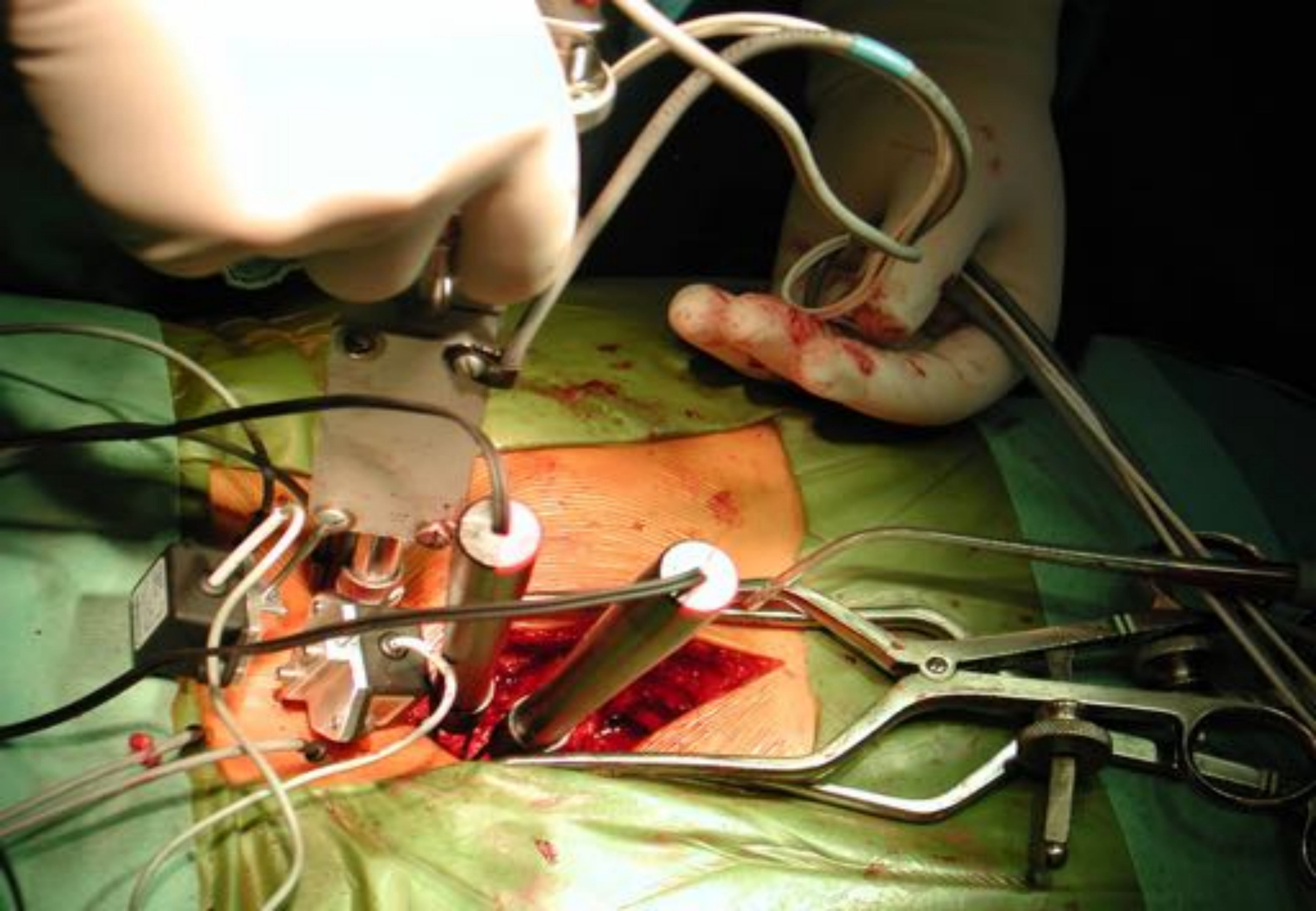


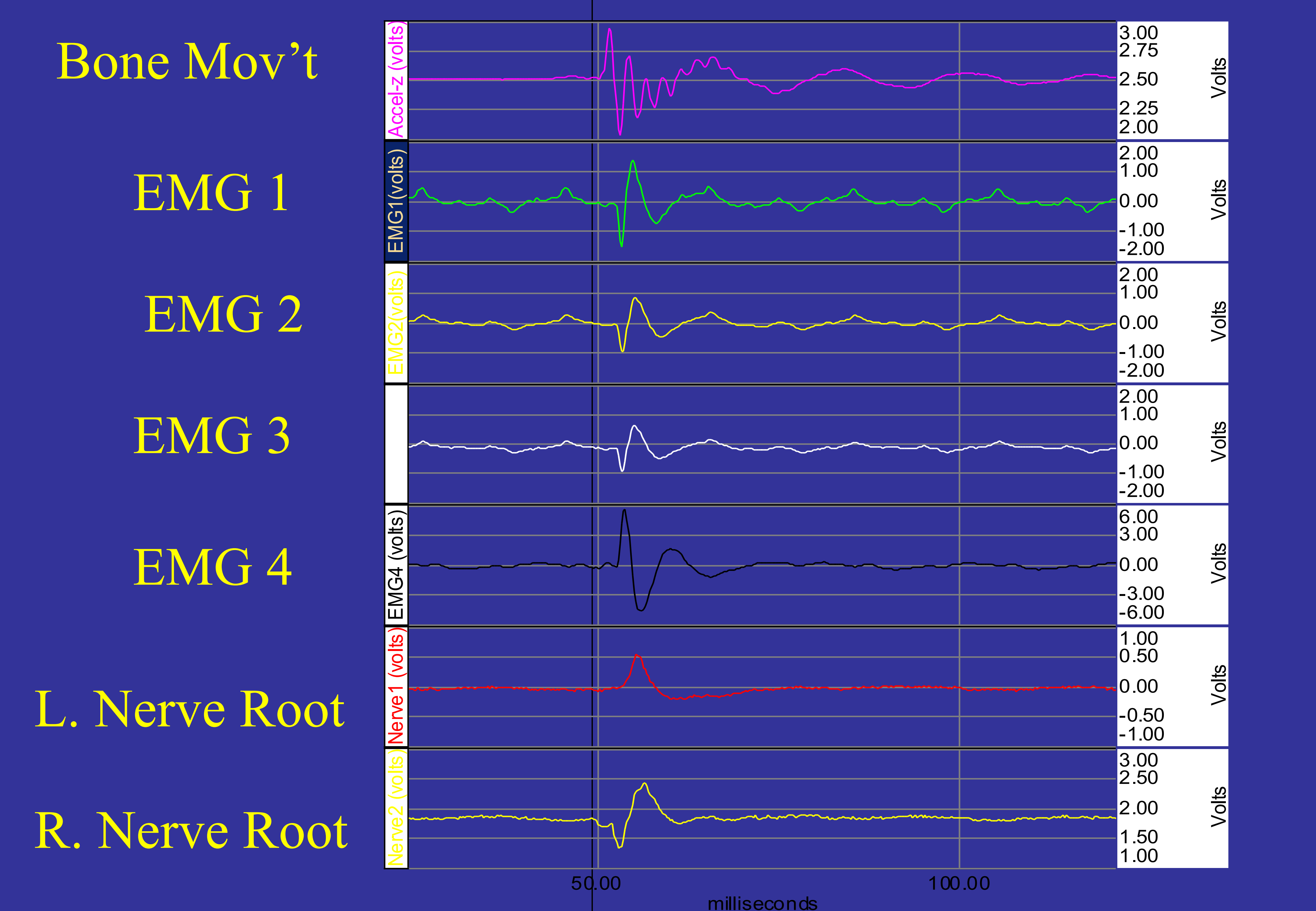




Materials
Protocol 2


Nerve Root
Electrodes





Bone Mov't
EMG 1
EMG 2
EMG 3
EMG 4
L. Nerve Root
R. Nerve Root
Accel-z (volts)
EMG1(volts)
EMG2(volts)
EMG4 (volts)
Nerve1 (volts)
Nerve2 (volts)
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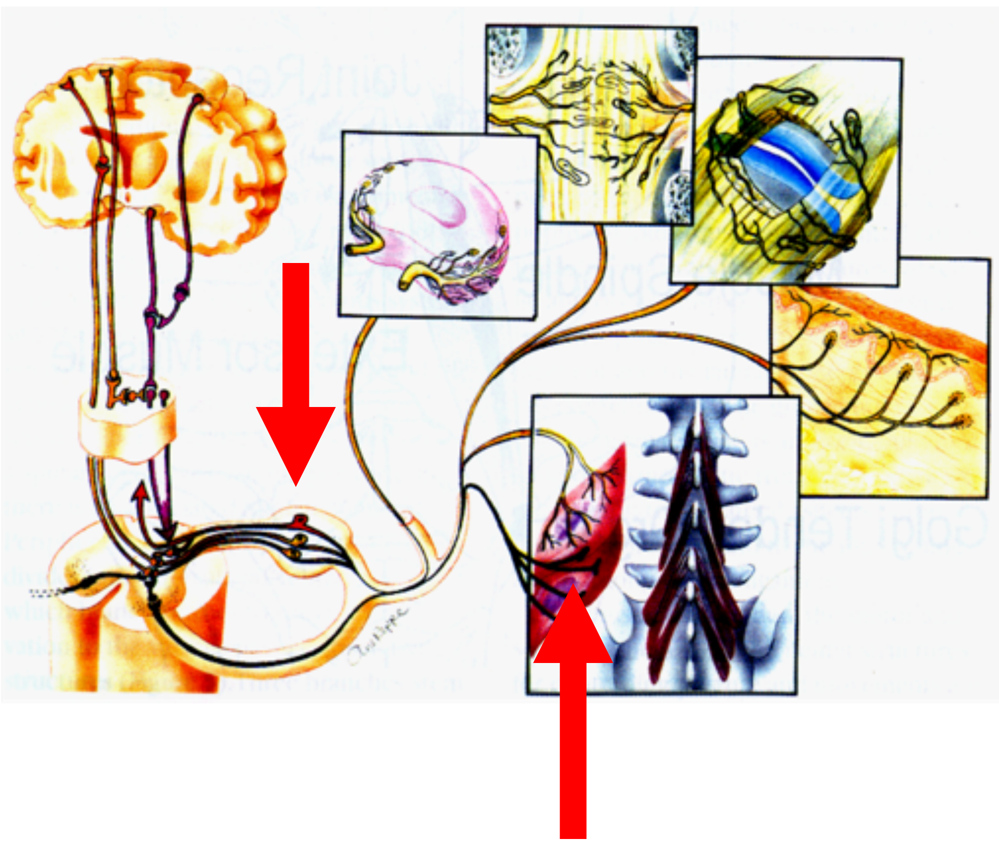
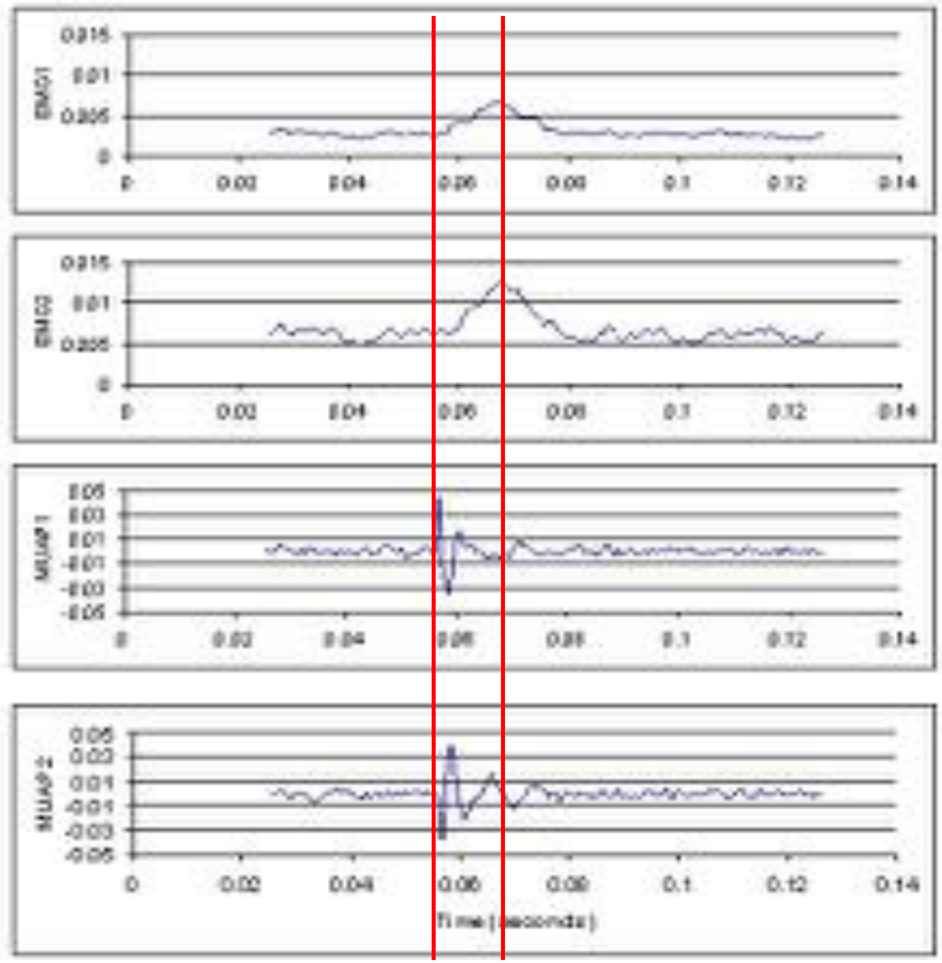
milliseconds

Belgium 1999, Neurophysiological Responses to SMT






EXIT

Prize-Winning Papers From the World Federation of Chiropractic 7th Biennial Congress

First Prize

Biomechanical and Neurophysiological Responses to Spinal Manipulation in Patients With Lumbar Radiculopathy

Christopher J. Colloca, DC,[a] Tony S. Keller, PhD,[b] and Robert Gunzburg, MD, PhD[c]

Abstract

Objective: The purpose of this study was to quantify in vivo vertebral motions and neurophysiological responses during spinal manipulation.

Methods: Nine patients undergoing lumbar decompression surgery participated in this study. Spinal manipulative thrusts (SMTs) (~5 ms; 30 N [Sham], 88 N, 117 N, and 150 N [max]) were administered to lumbar spine facet joints (FJs) and spinous processes (SPs) adjacent to an intraosseous pin with an attached triaxial accelerometer and bipolar electrodes cradled around the S1 spinal nerve roots. Peak baseline amplitude compound action potential (CAP) response and peak-peak amplitude axial (AX), posterior-anterior (PA), and medial-lateral (ML) acceleration time and displacement time responses were computed for each SMT. Within-subject statistical analyses of the effects of contact point and force magnitude on vertebral displacements and CAP responses were performed.

Results: SMTs (≥ 88 N) resulted in significantly greater peak-to-peak ML, PA, and AX vertebral displacements compared with sham thrusts ($P < .002$). SMTs delivered to the FJs resulted in approximately 3-fold greater ML motions compared with SPs ($P < .001$). SMTs over the SPs resulted in significantly greater AX displacements compared with SMTs applied to the FJs ($P < .05$). Seventy-five percent of SMTs resulted in positive CAP responses with a mean latency of 12.0 ms. Collectively, the magnitude of the CAP responses was significantly greater for max setting SMTs compared with sham ($P < .01$).

Conclusions: Impulsive SMTs in human subjects were found to stimulate spinal nerve root responses that were temporally related to the onset of vertebral motion. Further work, including examination of the frequency and force duration dependency of SMT, is necessary to elucidate the clinical relevance of enhanced or absent CAP responses in patients. (J Manipulative Physiol Ther 2004;27:1-15)

Key Indexing Terms: *Chiropractic Manipulation; Vertebral Motion; Neurophysiology*

Neuromechanical Characterization of in vivo Lumbar Spinal Manipulation. Part I. Vertebral Motion

Tony S. Keller, PhD,[a] Christopher J. Colloca, DC,[b] and Robert Gunzburg, MD, PhD[c]

Abstract

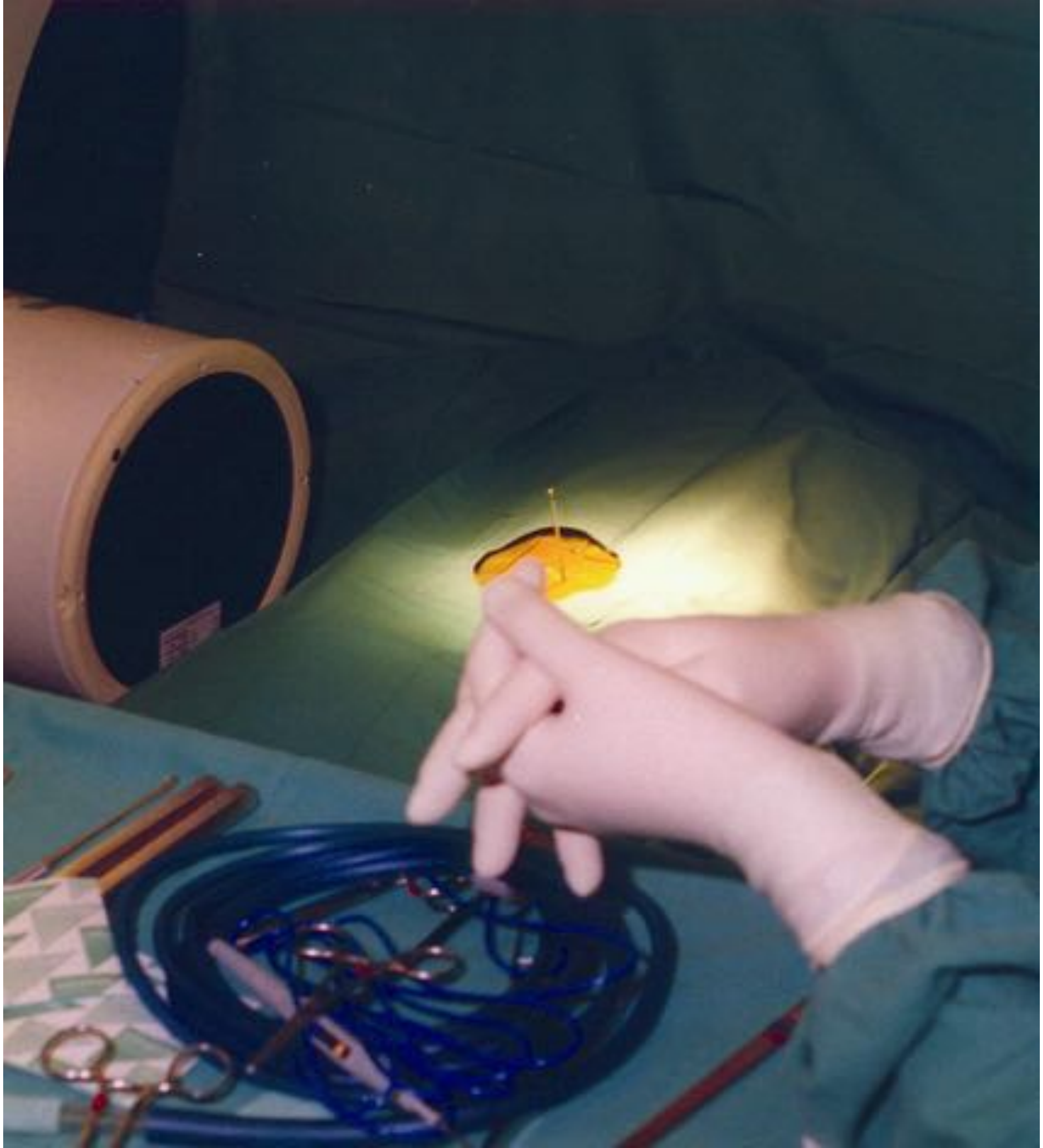
Objective: To quantify in vivo spinal motions and coupling patterns occurring in human subjects in response to mechanical force, manually assisted, short-lever spinal manipulative thrusts (SMTs) applied to varying vertebral contact points and utilizing various excursion (force) settings.

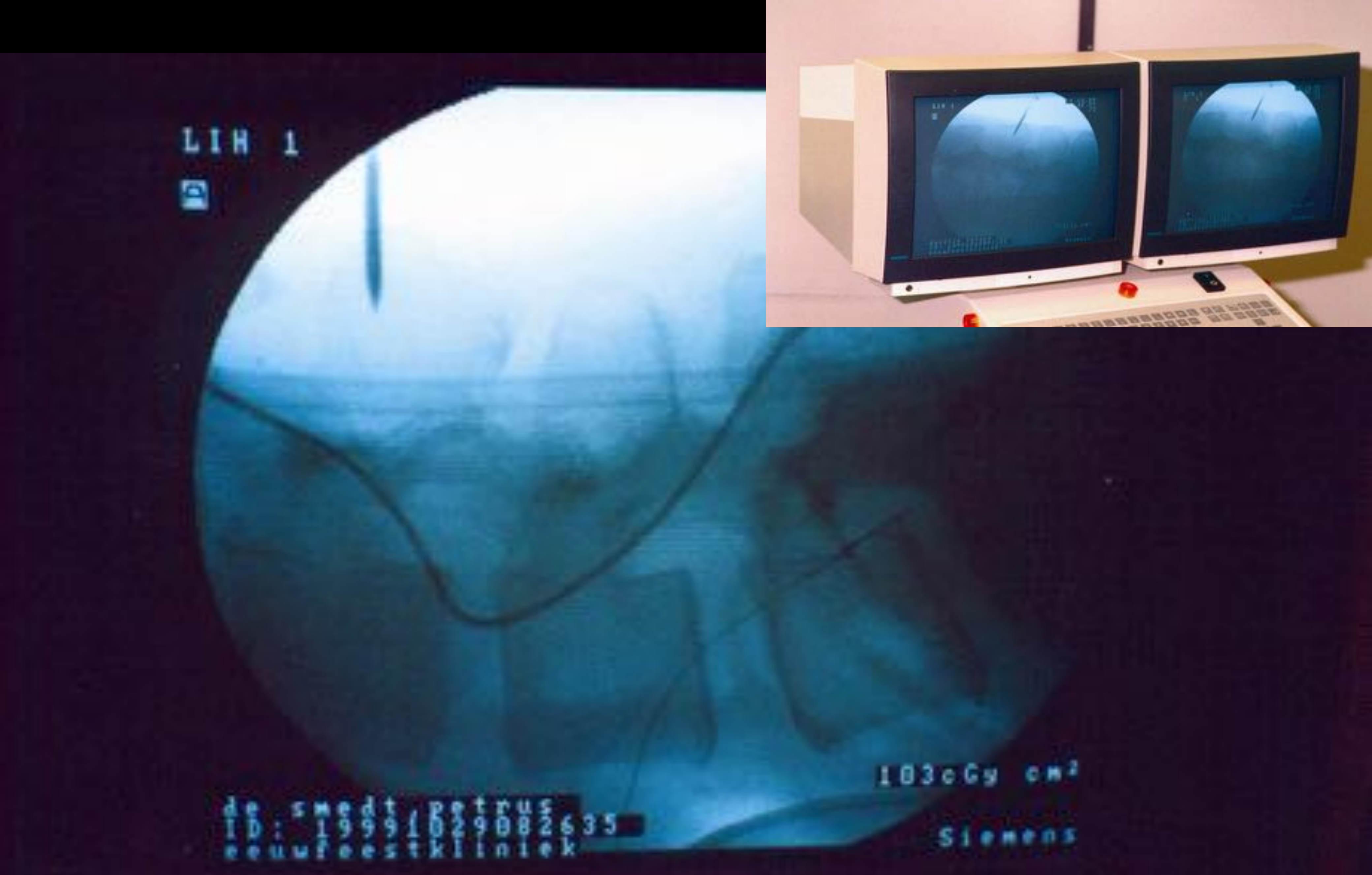
Methods: Triaxial accelerometers were attached to intraosseous pins rigidly fixed to the L1, L3, or L4 lumbar spinous process of 4 patients (2 male, 2 female) undergoing lumbar decompressive surgery. Lumbar spine acceleration responses were recorded during the application of 14 externally applied posteroanterior (PA) impulsive SMTs (4 force settings and 3 contact points) in each of the 4 subjects. Displacement time responses in the PA, axial (AX), and medial-lateral (ML) axes were obtained, as were intervertebral (L3-4) motion responses in 1 subject. Statistical analysis of the effects of facet joint (FJ) contact point and force magnitude on peak-to-peak displacements was performed. Motion coupling between the 3 coordinate axes of the vertebrae was examined using a least squares linear regression.

Results: SMT forces ranged from 30 N (lowest setting) to 150 N (maximum setting). Peak-to-peak ML, PA, and AX vertebral displacements increased significantly with increasing applied force. For thrusts delivered over the FJs, pronounced coupling was observed between all axes (AX-ML, AX-PA, PA-ML) (linear regression, $R^2 = 0.35$-0.52, $P < .001$), whereas only the AX and PA axes showed a significant degree of coupling for thrusts delivered to the spinous processes (SPs) (linear regression, $R^2 = 0.82$, $P < .001$). The ML and PA motion responses were significantly ($P < .05$) greater than the AX response for all SMT force settings. PA vertebral displacements decreased significantly ($P < .05$) when the FJ contact point was caudal to the pin compared with FJ contact cranial to the pin. FJ contact at the level of the pin produced significantly greater ML vertebral displacements in comparison with contact above and below the pin. SMTs over the spinous processes produced significantly ($P < .05$) greater PA and AX displacements in comparison with ML displacements. The combined ML, PA, and AX peak-to-peak displacements for the 4 force settings and 2 contact points ranged from 0.15 to 0.66 mm, 0.15 to 0.81 mm, and 0.07 to 0.45 mm, respectively. Intervertebral motions were of similar amplitude as the vertebral motions.

Conclusions: In vivo kinematic measurements of the lumbar spine during the application of SMTs over the FJs and SPs corroborate previous spinous process measurements in human subjects. Our findings demonstrate that PA, ML, and AX spinal motions are coupled and dependent on applied force and contact point. (J Manipulative Physiol Ther 2003;26:567-78)

Key Indexing Terms: *Acceleration; Biomechanics; Chiropractic; Kinematics; Lumbar Spine; Manipulation*

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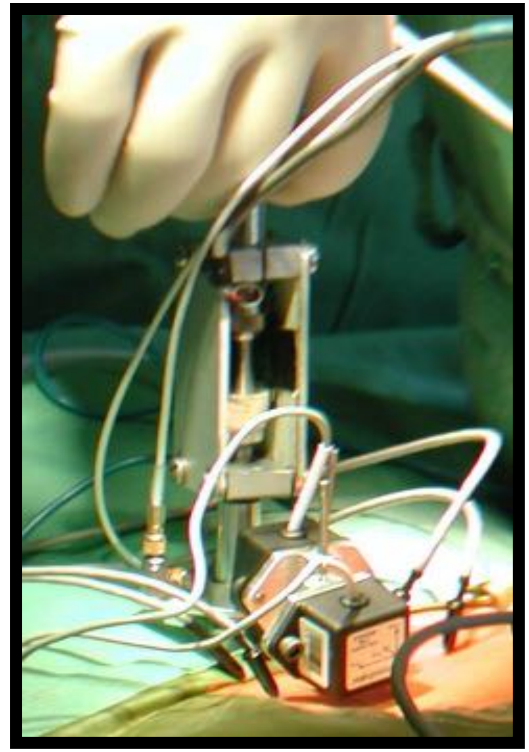


AAI w/ pre-load control frame

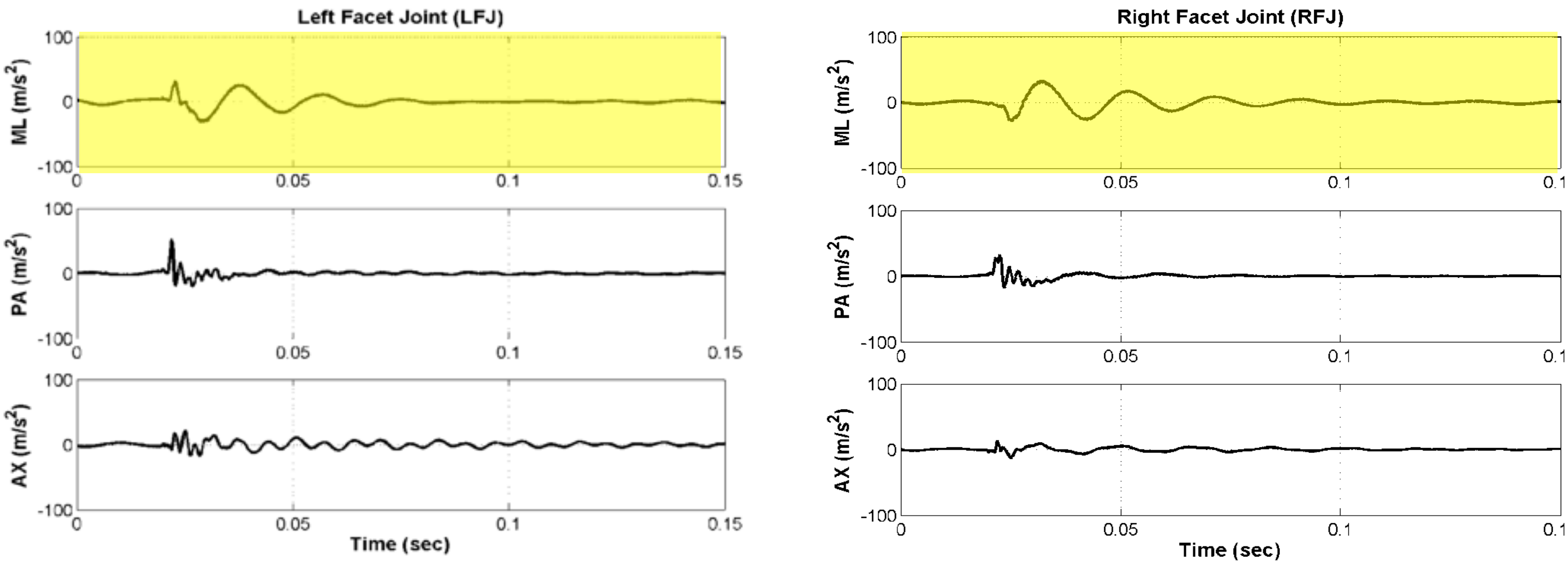
- input force
- acceleration response

Dual Three-Axis Accelerometers

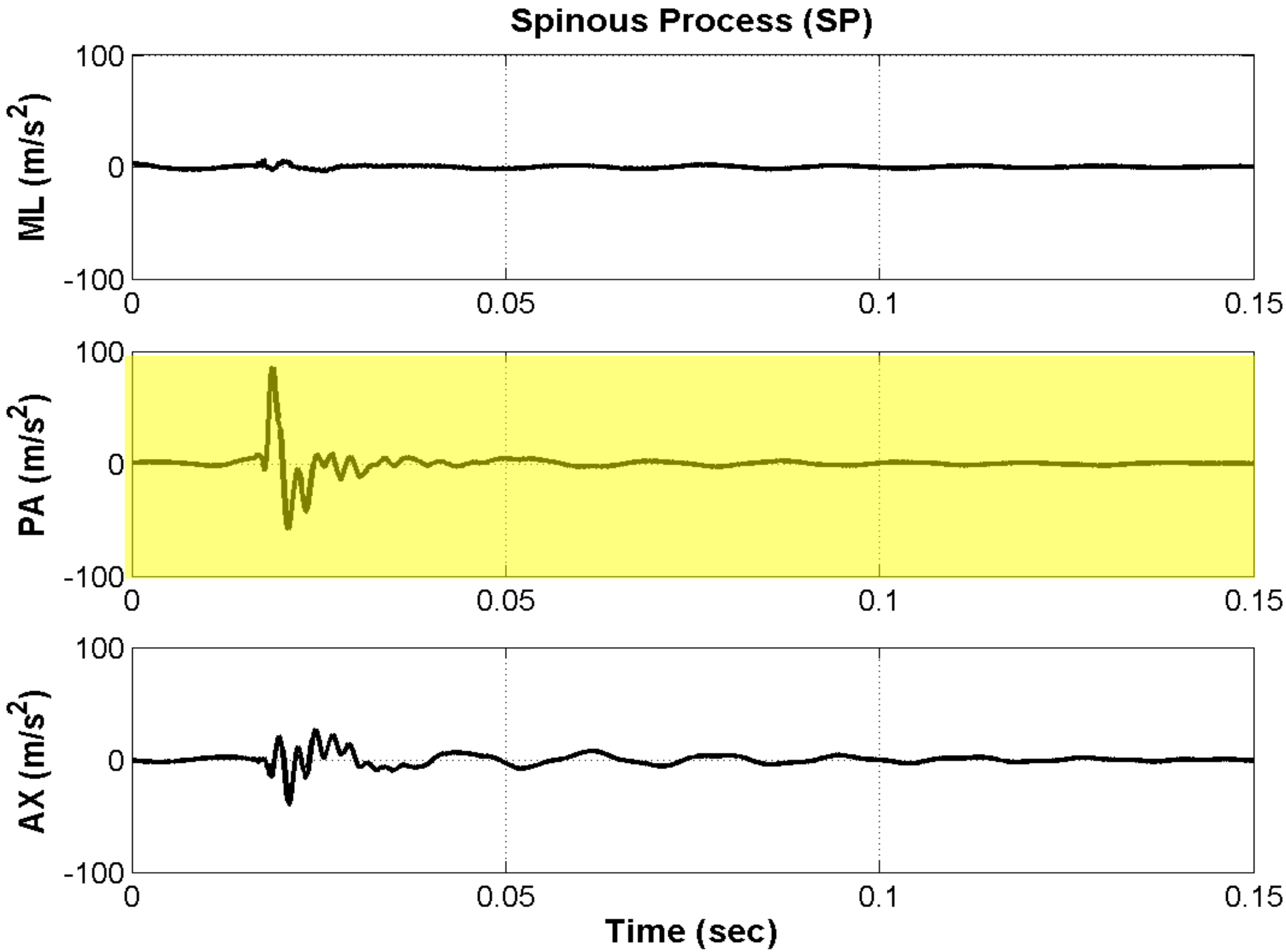
1. L3
2. L4

Patient 003

Biomechanical Responses



Biomechanical Responses

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Biomechancial Quantification of Pathologic Manipulable Spinal Lesions: An In Vivo Ovine Model of Spondylolysis and Intervertebral Disc Degeneration

Christopher J. Colloca, DC,[a] Robert Gunzburg, MD, PhD,[b] Brian J. Freeman, MD,[c] Marek Szpalski, MD,[d] Mostafa Afifi, PhD,[e] and Robert J. Moore, PhD[f]

Abstract

Objective: The purposes of this study were to quantify the biomechanical and pathologic consequences of surgically induced spinal lesions and to determine their response to spinal manipulation (SMT) in an in vivo ovine model.

Methods: Of 24 Merino sheep, 6 received L5 spondylolytic defects, 6 received L1 annular lesions, and 12 served as respective controls. Dorsoventral (DV) stiffness was assessed using oscillatory loads (2-12 Hz). Two SMT force-time profiles were administered in each of the groups using a randomized and repeated-measures design. Stiffness and the effect of SMT on the DV motions and multifidus needle electromyographic responses were assessed using a repeated-measures analysis of variance (α = .05). Postmortem histologic analysis and computed tomography validated the presence of lesions.

Results: L5 DV stiffness was significantly increased (40.2%) in the spondylolysis (6.28 N/mm) compared with the L5 control group (4.48 N/mm) ($P < .03$). Spinal manipulations delivered to the spondylolysis group resulted in less DV vertebral displacement ($P < .01$) compared with controls. Dorsoventral stiffness of the disc degeneration group was 5.66 N/mm, 94.5% greater than in the L1 control group (2.91 N/mm) ($P < .01$). One hundred–millisecond SMTs resulted in significantly reduced DV displacements in the disc degeneration group compared with the L1 control group ($P < .01$). Animals in the disc degeneration group showed a consistent 25% to 30% reduction in needle electromyographic responses to all SMTs.

Conclusions: Quantifiable objective evidence of spinal lesions and their response to SMT were confirmed in this study. Neuromechanical alterations provide novel insights into quantifying manipulable spinal lesions and a means to biomechanically assess SMT outcomes. (J Manipulative Physiol Ther 2012;35:354-366)

Key Indexing Terms: *Biomechanics; Manipulation, Spinal; Spondylolysis; Intervertebral Disc Degener Chiropractic*

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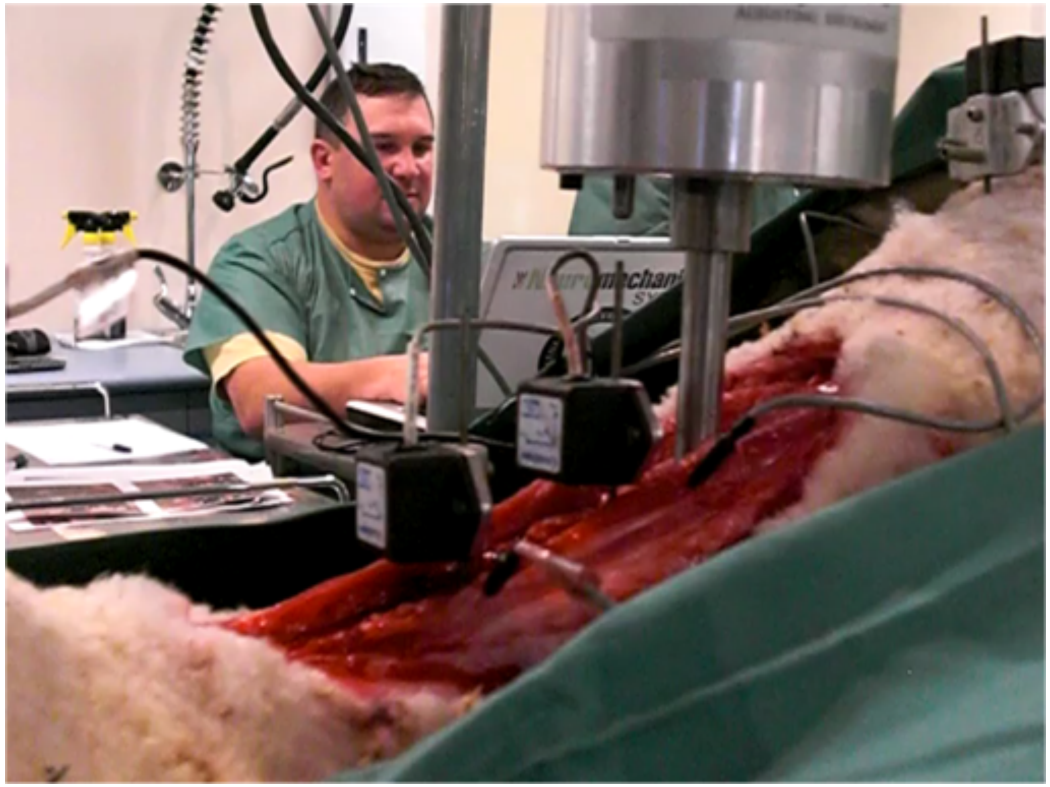
Methods



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Three-Dimensional Vertebral Motions Produced by Mechanical Force Spinal Manipulation

Tony S. Keller, PhD,[a] Christopher J. Colloca, DC,[b] Robert J. Moore, PhD,[c] Robert Gunzburg, MD, PhD,[d] Deed E. Harrison, DC,[e] and Donald D. Harrison, DC[f]

Abstract

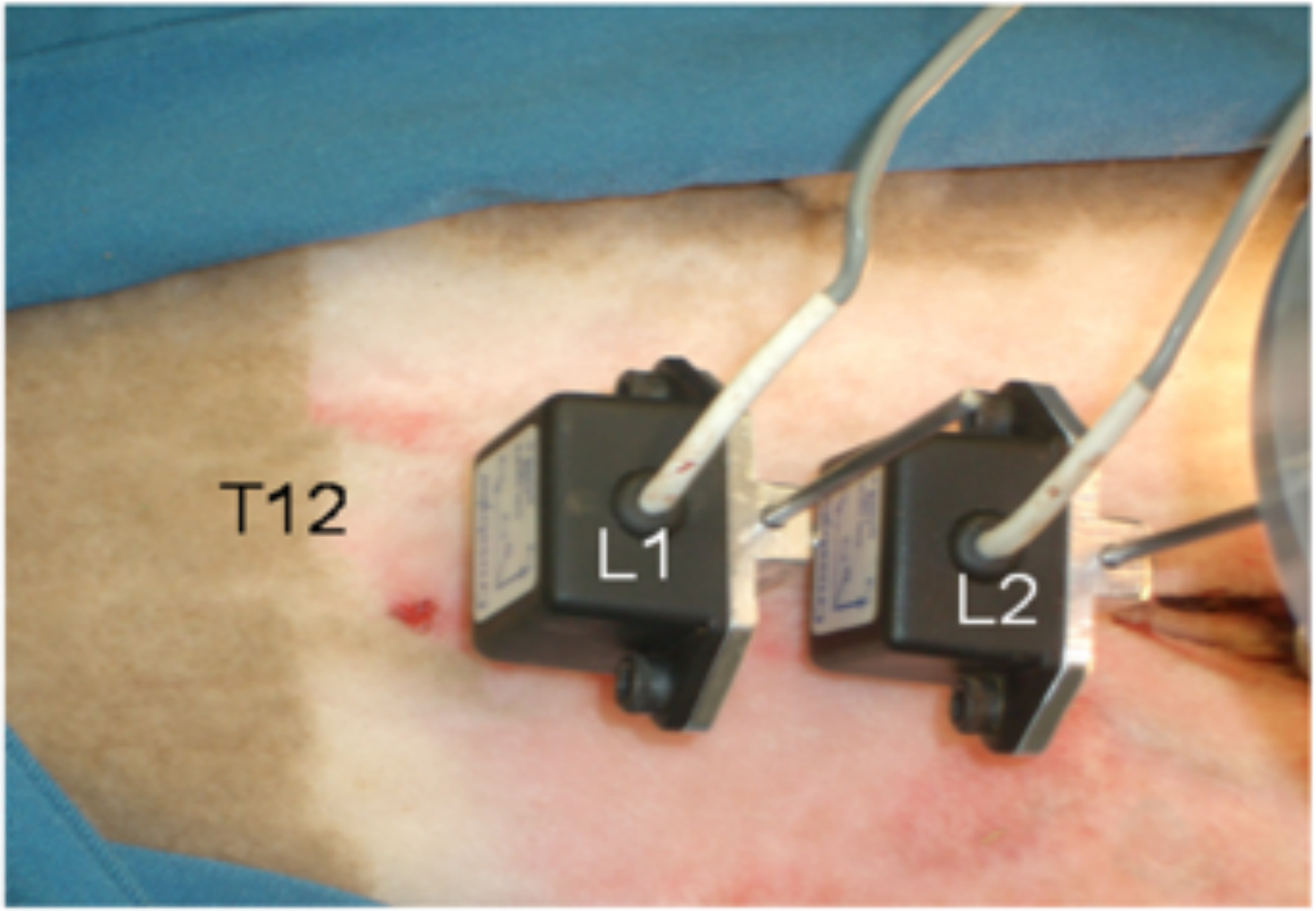
Objective: The aim of this study was to quantify and compare the 3-dimensional intersegmental motion responses produced by 3 commonly used chiropractic adjusting instruments.

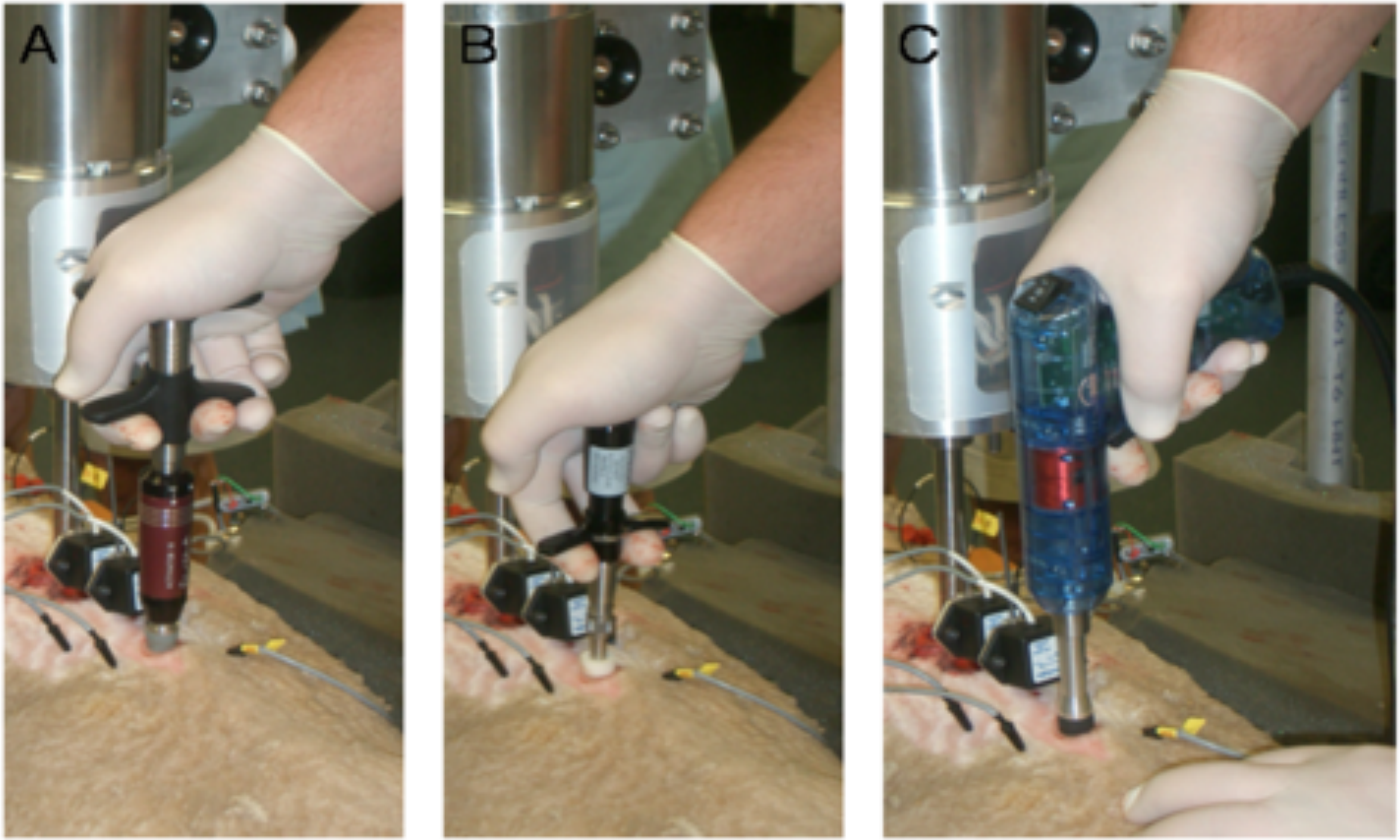
Methods: Six adolescent Merino sheep were examined at the Institute for Medical and Veterinary Science, Adelaide, Australia. In all animals, triaxial accelerometers were attached to intraosseous pins rigidly fixed to the L1 and L2 spinous processes under fluoroscopic guidance. Three handheld mechanical force chiropractic adjusting instruments (Chiropractic Adjusting Tool [CAT], Activator Adjusting Instrument IV [Activator IV], and the Impulse Adjusting Instrument [Impulse]) were used to randomly apply posteroanterior (PA) spinal manipulative thrusts to the spinous process of T12. Three force settings (low, medium, and high) and a fourth setting (Activator IV only) were applied in a randomized repeated measures design. Acceleration responses in adjacent segments (L1 and L2) were recorded at 5 kHz. The multiaxial intersegmental (L1-L2) acceleration and displacement response at each force setting was computed and compared among the 3 devices using a repeated measures analysis of variance (α = .05).

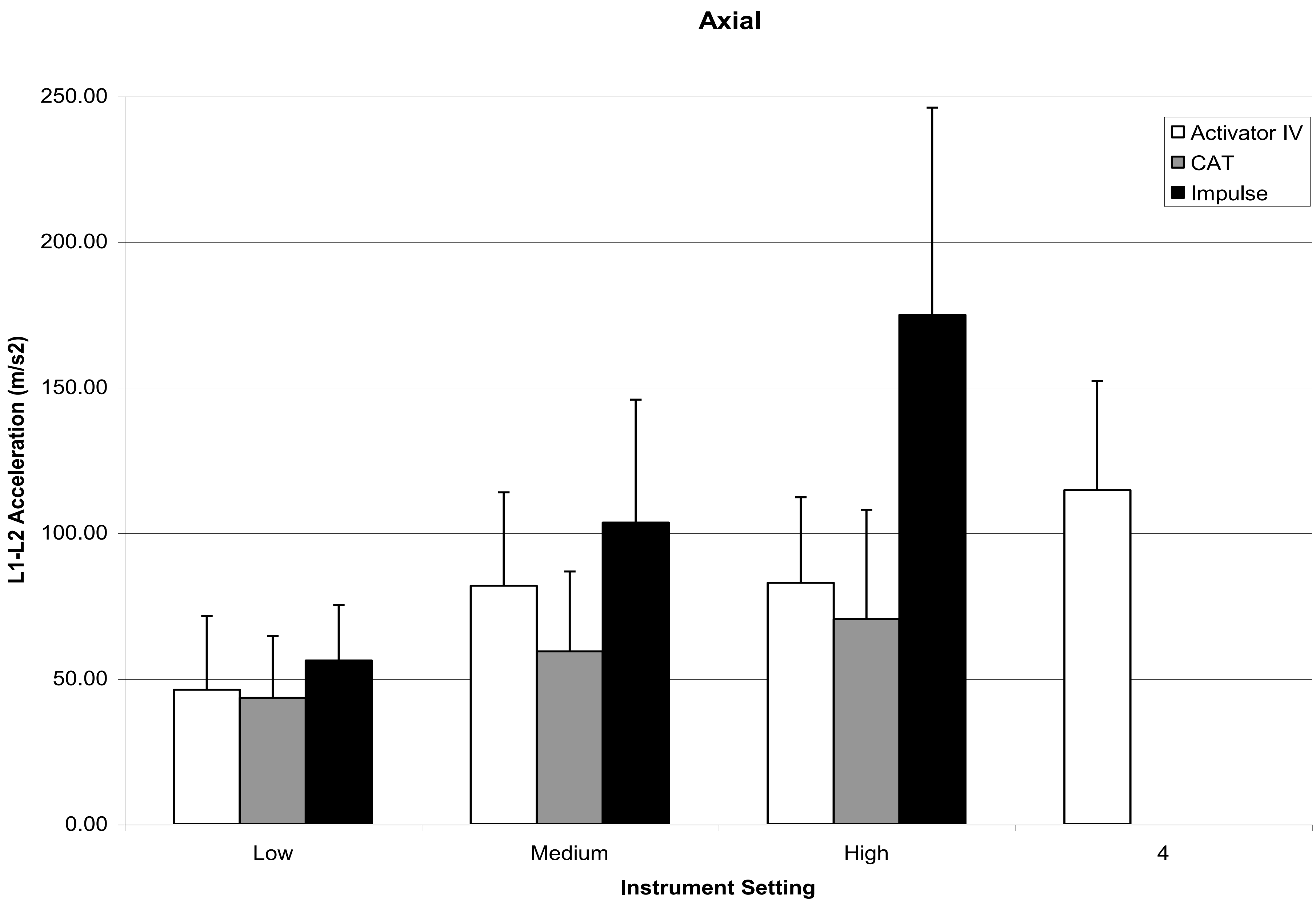
Results: For all devices, intersegmental motion responses were greatest for axial, followed by PA and medial-lateral (ML) measurement axes for the data examined. Displacements ranged from 0.11 mm (ML axis, Activator IV low setting) to 1.76 mm (PA axis, Impulse high setting). Compared with the mechanical (spring) adjusting instruments (CAT, Activator IV), the electromechanical Impulse produced the most linear increase in both force and intersegmental motion response and resulted in the greatest acceleration and displacement responses (high setting). Significantly larger magnitude intersegmental motion responses were observed for Activator IV vs CAT at the medium and high settings ($P < .05$). Significantly larger-magnitude PA intersegmental acceleration and displacement responses were consistently observed for Impulse compared with Activator IV and CAT for the high force setting ($P < .05$).

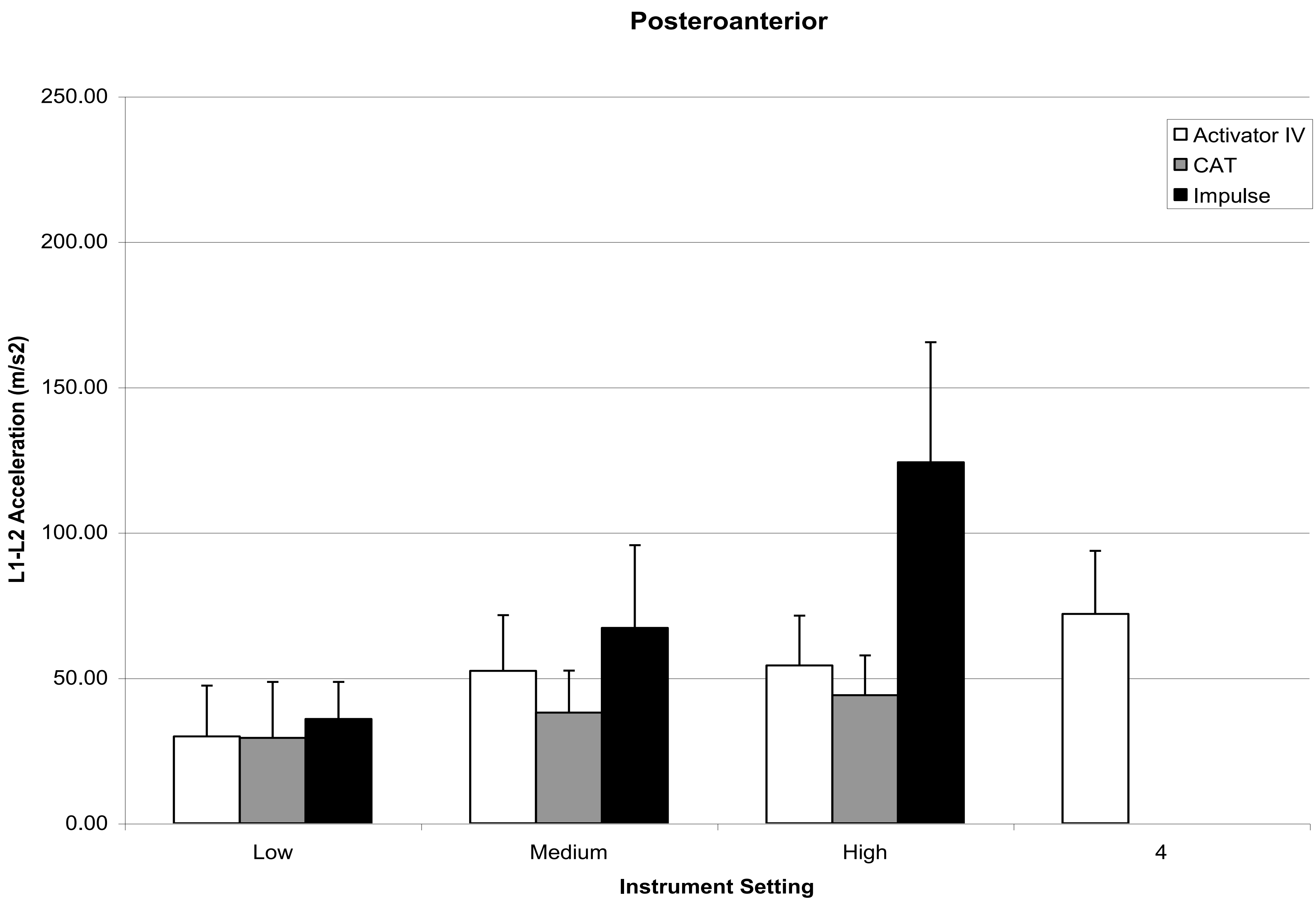
Conclusions: Larger-magnitude, 3D intersegmental displacement and acceleration responses were observed for spinal manipulative thrusts delivered with Impulse at most force settings and always at the high force setting. Our results indicate that the force-time characteristics of impulsive-type adjusting instruments significantly affects spinal motion and suggests that instruments can and should be tuned to provide optimal force delivery. (J Manipulative Physiol Ther 2006;29:425-436)

Key Indexing Terms: *Biomechanics; Chiropractic; Manipulation, Spinal; Spine; Mechanical Force*


T12
L1
L2


A
B
C


Axial
L1-L2 Acceleration (m/s2)
250.00
200.00
150.00
100.00
50.00
0.00
Activator IV
CAT
Impulse
Low
Medium
High
4
Instrument Setting


Posteroanterior
250.00
200.00
150.00
100.00
50.00
0.00
L1-L2 Acceleration (m/s2)
Activator IV
CAT
Impulse
Low
Medium
High
4
Instrument Setting

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Clinical Biomechanics 17 (2002) 185–196

CLINICAL BIOMECHANICS

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Force-deformation response of the lumbar spine: a sagittal plane model of posteroanterior manipulation and mobilization

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[a] Department of Mechanical Engineering, Department of Orthopaedics and Rehabilitation, University of Vermont, 119C Votey Building, Burlington 05405-0156, Vermont, USA

[b] Postgraduate and Continuing Education Department Faculty, New York Chiropractic College, Seneca Falls, New York, USA, State of the Art Chiropractic Center, P.C., Phoenix, AZ, USA

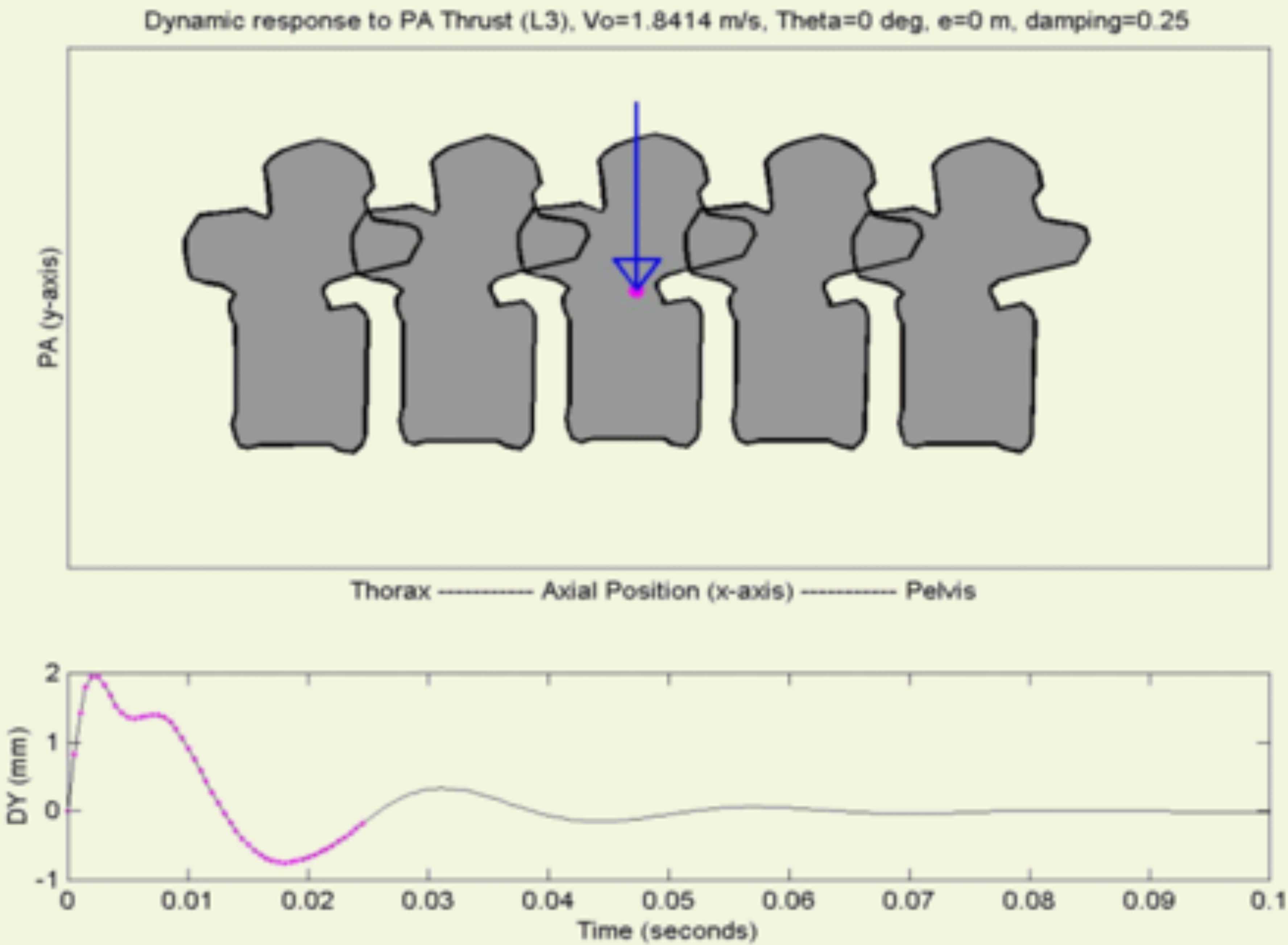
[c] Department of Civil and Environmental Engineering, University of Vermont, Burlington, Vermont, USA

Received 9 January 2001; accepted 10 January 2001

Relevance

This study assists clinicians to understand the biomechanics of posteroanterior forces applied to the lumbar spine of prone-lying subjects. Of particular clinical relevance is the finding that greater spinal mobility is possible by targeting specific load-time histories.

Keywords: Biomechanics; Dynamic simulation; Lumbar spine; Manipulation; Model; Natural frequency; Rigid body; Spine; Vibration



Dynamic response to PA Thrust (L3), Vo=1.8414 m/s, Theta=0 deg, e=0 m, damping=0.25
PA (y-axis)
Thorax ---------- Axial Position (x-axis) ---------- Pelvis
DY (mm)
2
1
0
-1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Time (seconds)

Chiropractic & Osteopathy

Research

Increased multiaxial lumbar motion responses during multiple-impulse mechanical force manually assisted spinal manipulation

Tony S Keller[1], Christopher J Colloca*[2], Robert J Moore[3], Robert Gunzburg[4] and Deed E Harrison[5]

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Email: Tony S Keller - keller@cems.uvm.edu; Christopher J Colloca* - DrC100@aol.com; Robert J Moore - rob.moore@imvs.sa.gov.au; Robert Gunzburg - robert@gunzburg.be; Deed E Harrison - drdeed@idealspine.com

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Accepted: 06 April 2006

This article is available from: http://www.chiroandosteo.com/content/14/1/6

Figure 1
Experimental setup illustrating the Impulse Adjusting Instrument® positioned over the T12 spinous process and the two triaxial accelerometers rigidly attached to stainless steel pins at L1 and L2.

Methods: Fifteen adolescent Merino sheep were examined. Tri-axial accelerometers were attached to intraosseous pins rigidly fixed to the L1 and L2 lumbar spinous processes under fluoroscopic guidance while the animals were anesthetized. A hand-held electromechanical chiropractic adjusting instrument (Impulse) was used to apply single and repeated force impulses (13 total over a 2.5 second time interval) at three different force settings (low, medium, and high) along the posteroanterior axis of the T12 spinous process. Axial (AX), posteroanterior (PA), and medial-lateral (ML) acceleration responses in adjacent segments (L1, L2) were recorded at a rate of 5000 samples per second. Peak-peak segmental accelerations (L1, L2) and intersegmental acceleration transfer (L1–L2) for each axis and each force setting were computed from the acceleration-time recordings. The initial acceleration response for a single thrust and the maximum acceleration response observed during the 12 multiple impulse trains were compared using a paired observations t-test (POTT, alpha = .05).

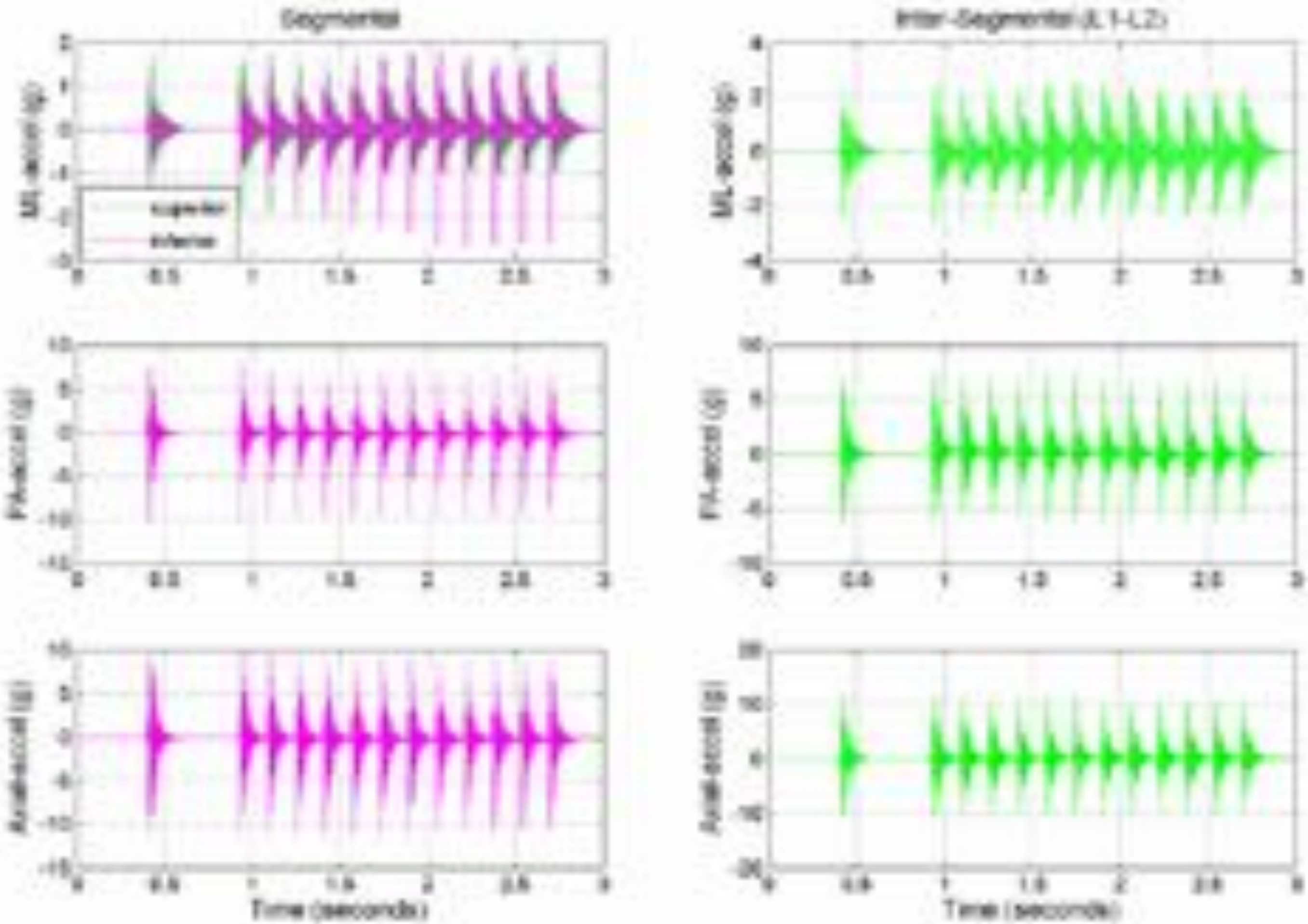
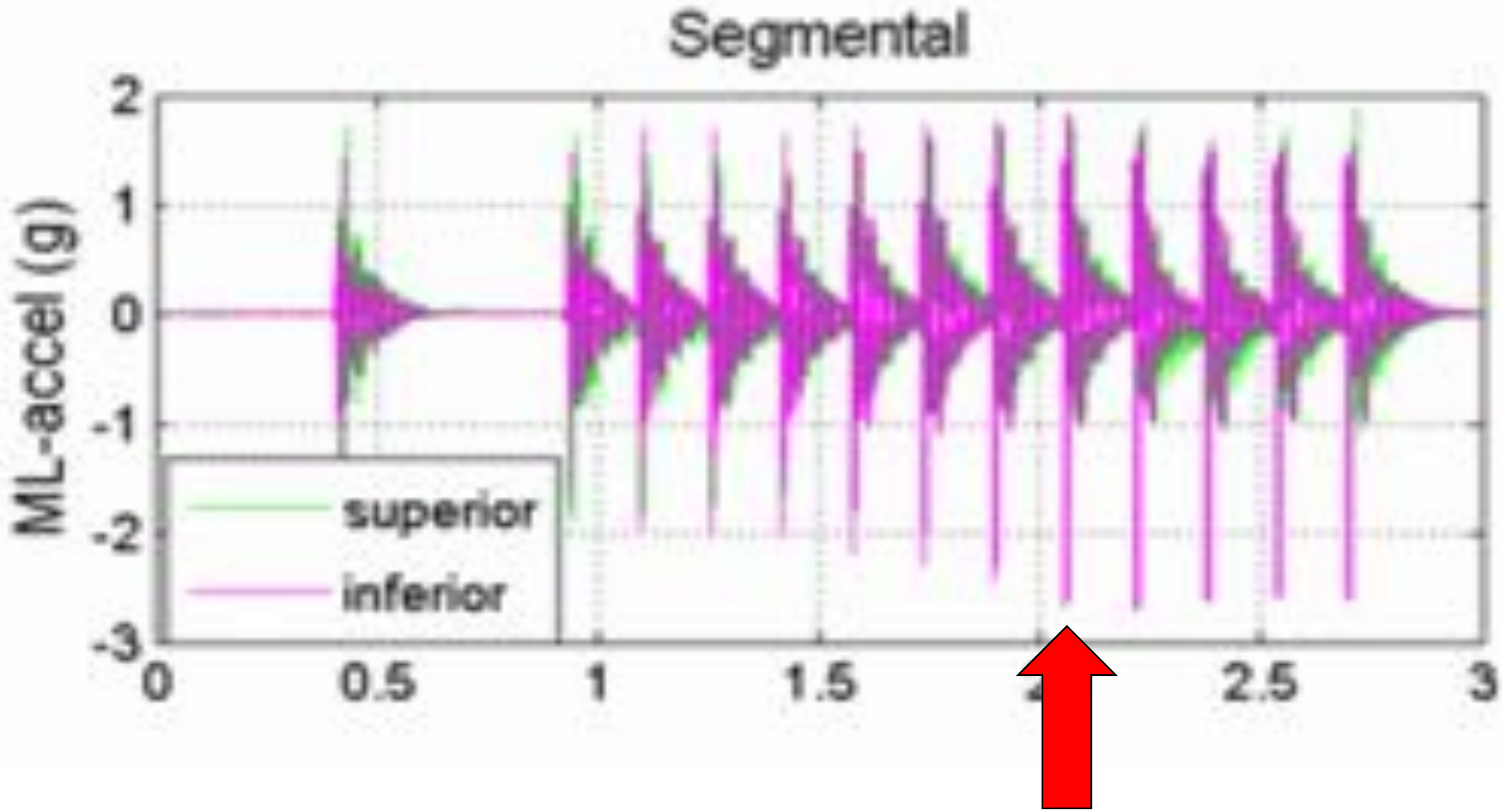


Figure 2
Typical segmental (L1, superior and L2, inferior) and intersegmental (L1-L2) medial-lateral (ML), posterior-anterior (PA), and axial acceleration responses (m/s^2) during the application of haversine-like mechanical excitation to the ovine spine (high force setting at T12 spinous process, 13 pulse trains).



Segmental
ML-accel (g)
2
1
0
-1
-2
-3
0
0.5
1
1.5
2
2.5
3
superior
inferior

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CLINICAL BIOMECHANICS

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Spinal manipulation force and duration affect vertebral movement and neuromuscular responses ☆

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[b] Department of Mechanical Engineering, and Department of Orthopaedics and Rehabilitation, University of Vermont, Burlington, VT, USA
[c] Chiropractic Biophysics Non-profit, Inc., Evanston, WY, USA
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JOURNAL OF BIOMECHANICS

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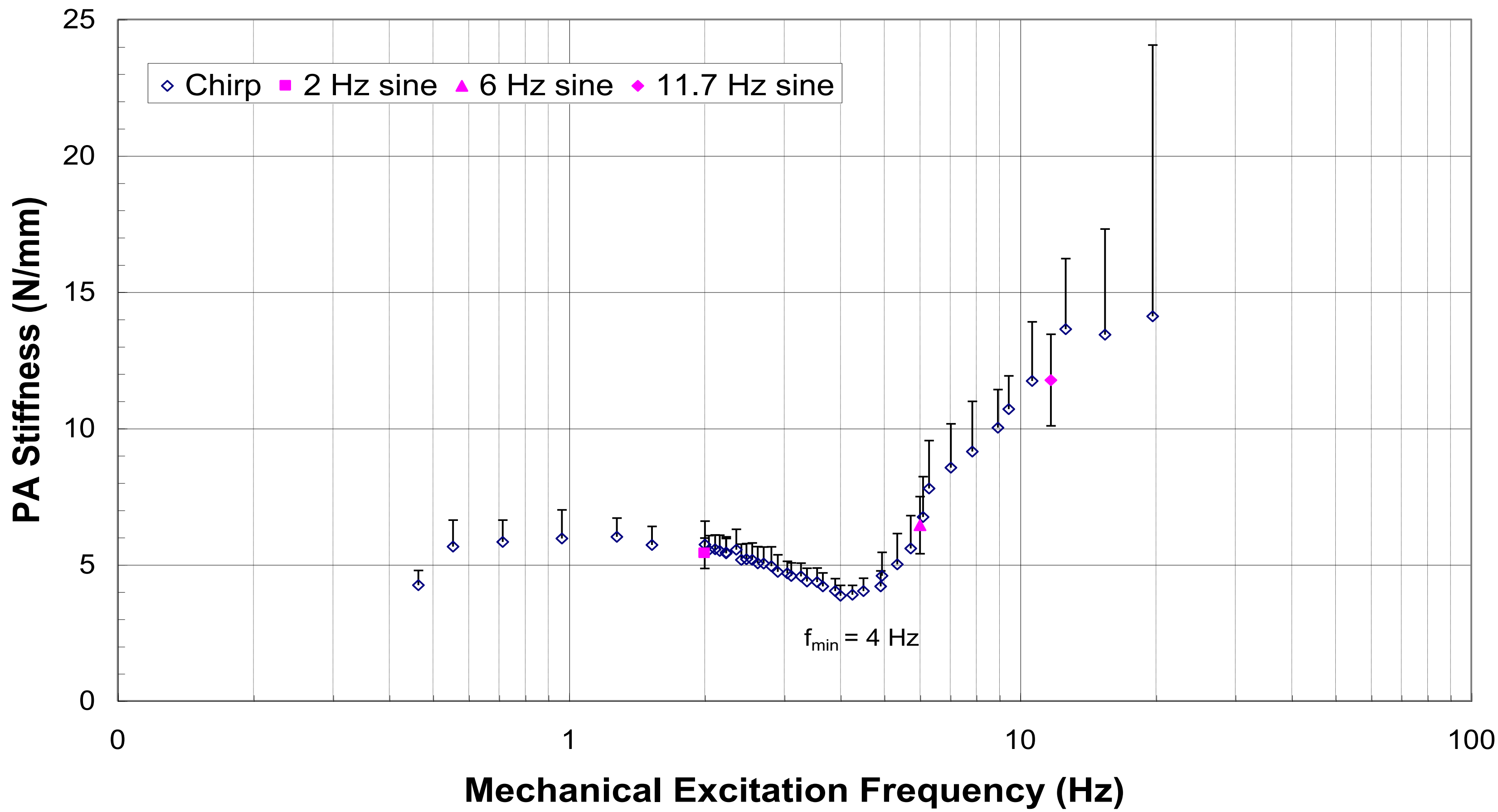
Dynamic dorsoventral stiffness assessment of the ovine lumbar spine

Tony S. Keller[a,*], Christopher J. Colloca[b]



SPINE Volume 32, Number 19, pp E544–E550

Intervertebral Disc Degeneration Reduces Vertebral Motion Responses

Christopher J. Colloca, DC,* Tony S. Keller, PhD,† Robert J. Moore, PhD,‡
Robert Gunzburg, MD, PhD,§ and Deed E. Harrison, DC||

Study Design. A prospective *in vivo* experimental animal study.

Objective. To determine the effects of disc degeneration and variable pulse duration mechanical excitation on dorsoventral lumbar kinematic responses.

Summary of Background Data. In vitro and in vivo biomechanical studies have examined spine kinematics during posteroanterior loading mimicking spinal manipulation therapy (SMT), but few (if any) studies have quantified SMT loading-induced spinal motion responses in the degenerated intervertebral disc.

Methods. Fifteen sheep underwent a survival surgical procedure resulting in chronic disc degeneration of the L1–L2 disc. Ten age- and weight-matched animals served as ontrols. Uniform pulse dorsoventral mechanical forces (80) were applied to the L3 spinous processes using 10-, 100-, d 200-ms duration pulses mimicking SMT. L3 displacent and L2–L1 acceleration in the control group were comd with the degenerated disc group.

esults. Dorsoventral displacements increased signifly (fivefold, $P < 0.001$) with increasing mechanical excitation pulse duration (control and degenerated disc groups). Displacements and L2–L1 acceleration transfer were significantly reduced (~19% and ~50%, respectively) in the degenerated disc group compared with control (100- and 200-ms pulse duration protocols, $P < 0.01$).

Conclusion. Dorsoventral vertebral motions are dependent on mechanical excitation pulse duration and are significantly reduced in animals with degenerated discs.

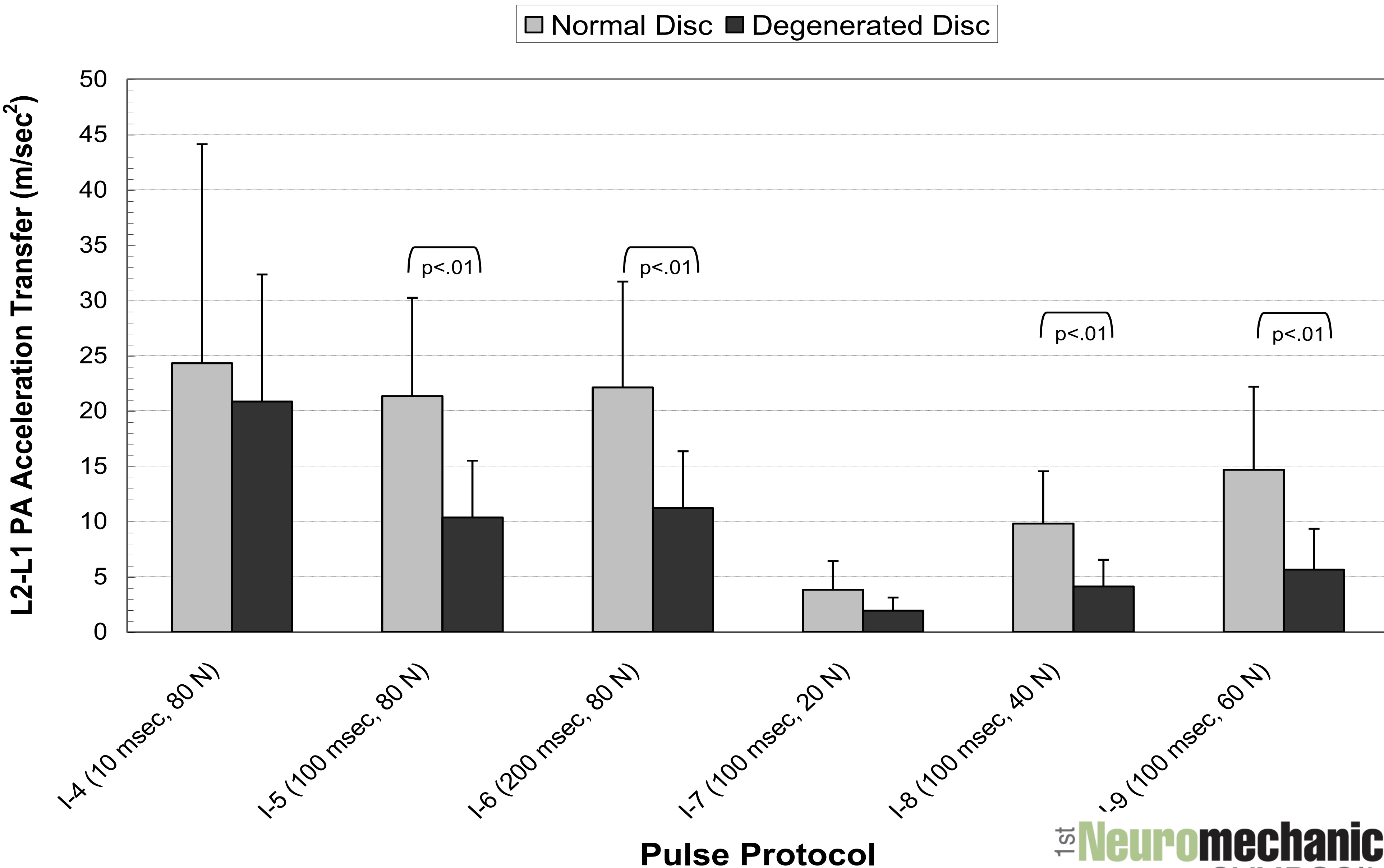
Key words: biomechanics, degeneration, intervertebral disc, manipulation, mobilization. **Spine 2007;32: E544–E550**

ing manual therapies.[1] Progressive degenerative changes of the IVD are associated with increased age, trauma, and abnormal postural loading.[2] Indeed, a large proportion of the population who receive manual therapies have some degree of disc disease.[1] To influence the peripheral pain generator, patients with discogenic disease commonly undergo spinal manipulative therapy (SMT) with the primary goal of normalizing loads and improving spinal mobility.[3]

A wide range of manual techniques have been developed providing clinicians with choices of force amplitude, speed, and vector among other variables of SMT delivery in patient care. Force-time characteristics, including the applied force magnitude, speed, and/or frequency, have therefore been attributed to the underlying mechanisms of SMT.[4] Both *in vitro*[5,6] and *in vivo*[7,8] biomechanical studies have examined segmental and intersegmental displacements and vibration responses during SMT, but few (if any) studies have quantified SMT-induced spinal kinematics in the degenerated IVD.

The purpose of this experimental study was to examine the *in vivo* motion behavior of the normal disc and degenerated disc ovine lumbar spine subjected to varying mechanical excitation force-time profiles. Disc degeneration was established using a validated animal model.[9] We hypothesized that vertebral kinematics would be reduced in animals with disc degeneration.

Intersegmental Motion Response to Varying Force-Time Profiles



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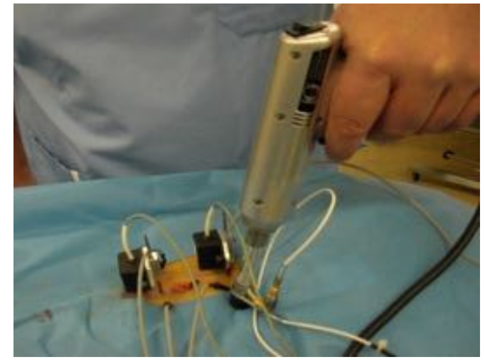
QUANTIFYING IN VIVO VERTEBRAL MOTIONS DURING IMPULSIVE SPINAL MANIPULATION

Christopher J. Colloca, DC[1] **Robert Gunzburg, MD, PhD**[2] **Marek Szpalski, MD**[3] **Mostafa Afifi, PhD**[4]

[1] Graduate Student, Biomechanics Laboratory, PhD Kinesiology Program, School of Nutrition and Health Promotion, Arizona State University, Tempe, Arizona, U.S.A.; [2]Department of Orthopaedic Surgery, Edith Cavell (CAV), Brussels, Belgium; [3]Department of Orthopaedic Surgery, Centre Hospital Moliere Longchamp, Brussels, Belgium; [4]Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada

Purpose

The purpose of this study is to quantify *in vivo* human lumbar spine motions during impulsive spinal manipulative therapy (SMT) delivery.



Methods

Tri-axial accelerometers were attached to intraosseous pins rigidly fixed to adjacent vertebrae at L4 and L5 spinous process of three patients undergoing lumbar decompressive surgery.

Lumbar spine acceleration responses were recorded during the application of 12 externally applied posteroanterior (PA) impulsive SMTs delivered by an Impulse iQ®.

Three force settings were delivered to two contact points (facet joint and spinous process) at two vectors (cranial and caudal) in a repeated measures design (n=144) in each subject.

Displacement-time responses in the PA, axial (AX) and medial-lateral (ML) axes were obtained from the acceleration-time histories using trapezoidal numerical integration.

Statistical analysis of the effects of contact point, force magnitude, and vector on peak-to-peak displacements was performed. Correlation of non-invasive stylus accelerations was compared to interosseous pin accelerations using least-squares linear regressions.

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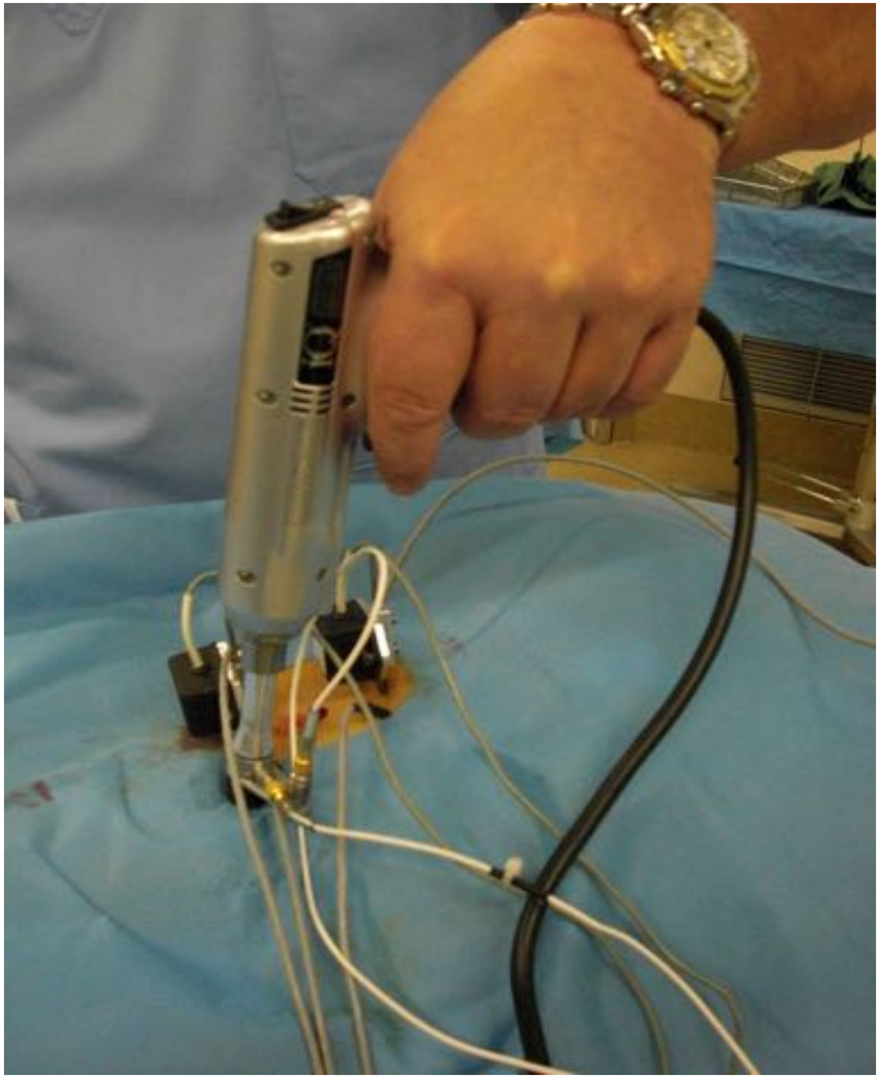
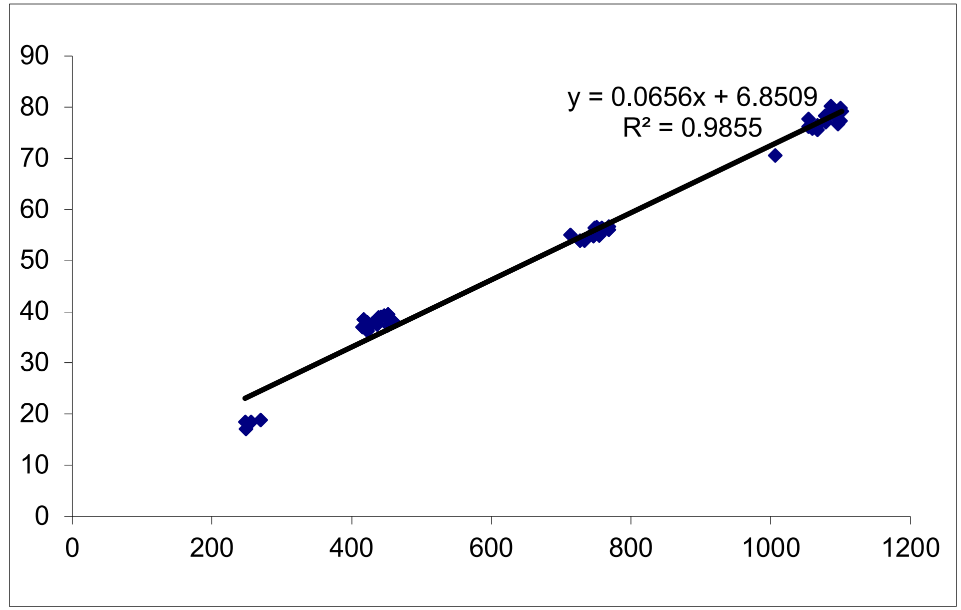
Proceedings of the
2013 International Society for Physical Medicine and Rehabilitation, Beijing, China, June 17-20, 2013.





y = 0.0656x + 6.8509
R² = 0.9855
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200

QUANTIFYING IN VIVO VERTEBRAL MOTIONS DURING IMPULSIVE SPINAL MANIPULATION

Christopher J. Colloca, DC[1] Robert Gunzburg, MD, PhD[2] Marek Szpalski, MD[3] Mostafa Afifi, PhD[4]

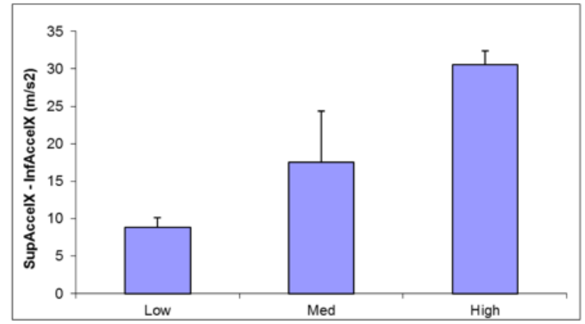
[1] Graduate Student, Biomechanics Laboratory, PhD Kinesiology Program, School of Nutrition and Health Promotion, Arizona State University, Tempe, Arizona, U.S.A.; [2]Department of Orthopaedic Surgery, Edith Cavell (CAV), Brussels, Belgium; [3]Department of Orthopaedic Surgery, Centre Hospital Moliere Longchamp, Brussels, Belgium; [4]Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada

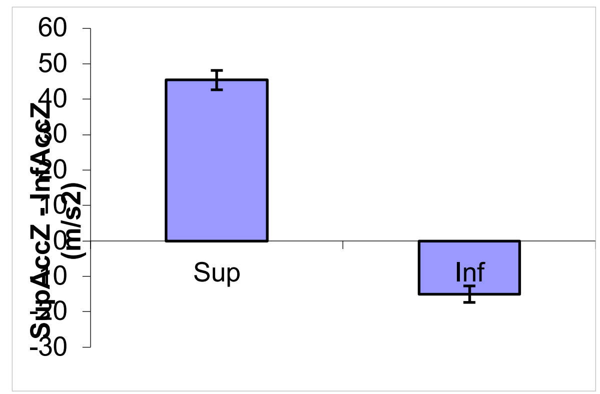
Results

Peak-to-peak ML, PA, AX vertebral motions increased significantly ($p<.05$) with increasing applied force.

Cranially directed SMTs created significantly greater L4-L5 motions compared to caudally directed thrusts ($p<.01$).

Contacts to the facet joints induced greater ML motions than those applied to the spinous processes ($p<.01$).





Proceedings of the
2013 International Society for Physical Medicine and Rehabilitation, Beijing, China, June 17-20, 2013.

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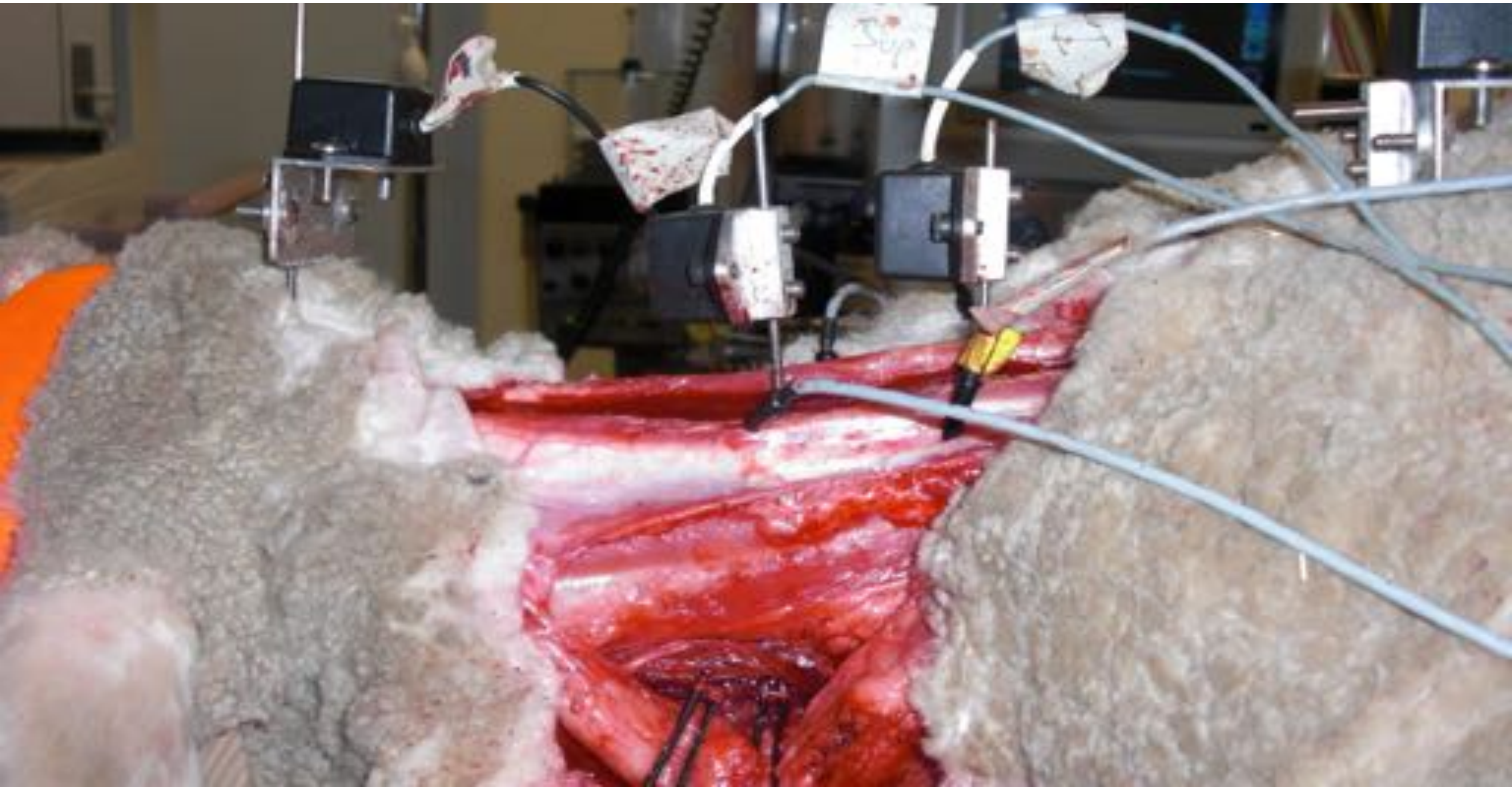
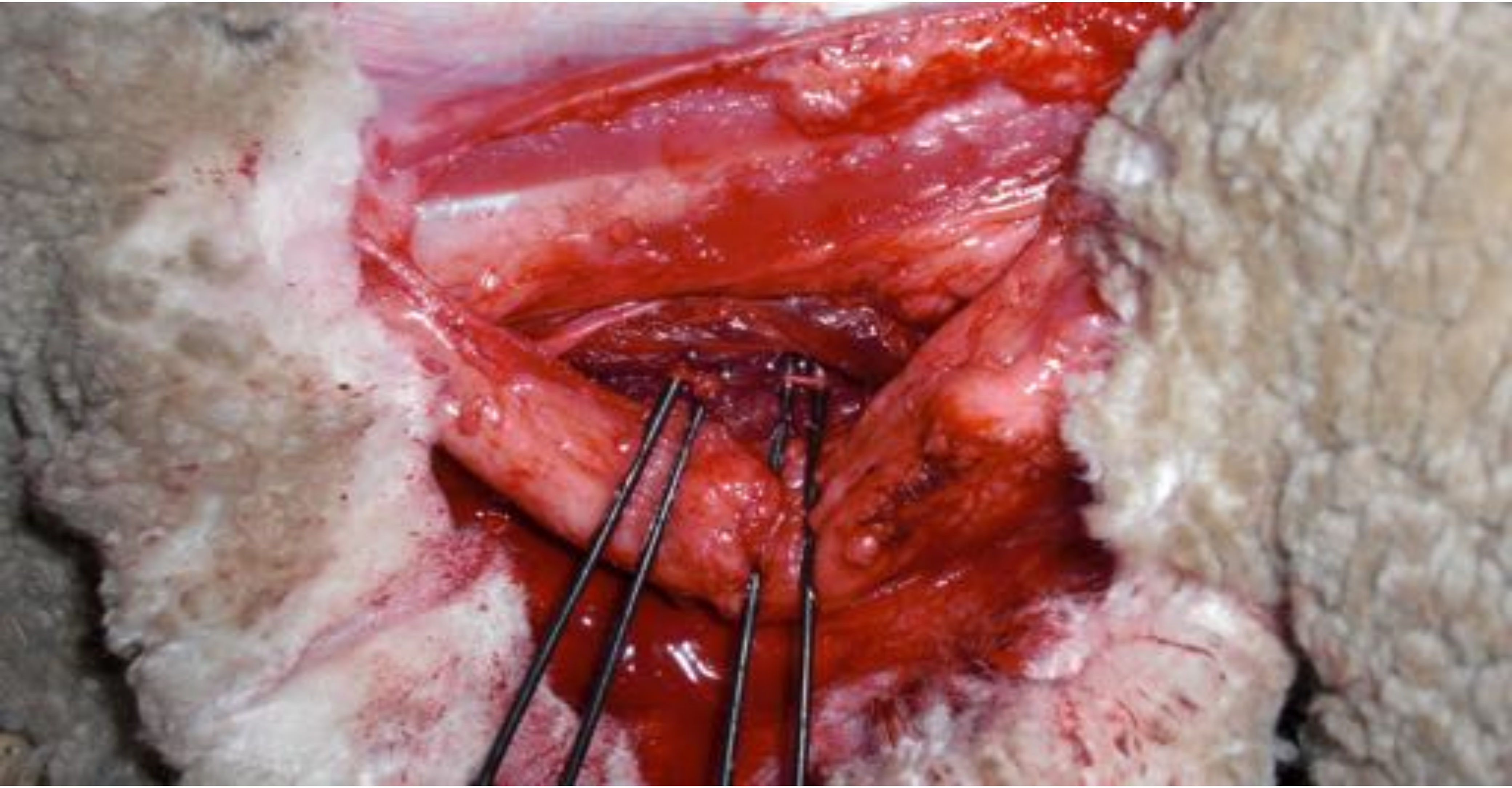
COLLOCA CJ, GUNZBURG R, MOORE RJ.
SOMATO-SYMPATHETIC RESPONSES TO CHIROPRACTIC ADJUSTMENTS IN A MODEL OF CERVICAL DISC DEGENERATION

COLLOCA CJ, GUNZBURG R, MOORE RJ.
SOMATO-SYMPATHETIC RESPONSES TO CHIROPRACTIC ADJUSTMENTS IN A MODEL OF CERVICAL DISC DEGENERATION

Australian Spinal Research Foundation



COLLOCA CJ, GUNZBURG R, MOORE RJ.
SOMATO-SYMPATHETIC RESPONSES TO CHIROPRACTIC ADJUSTMENTS IN A MODEL OF CERVICAL DISC DEGENERATION



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AUSTRALIAN spinal research FOUNDATION

[redacted]

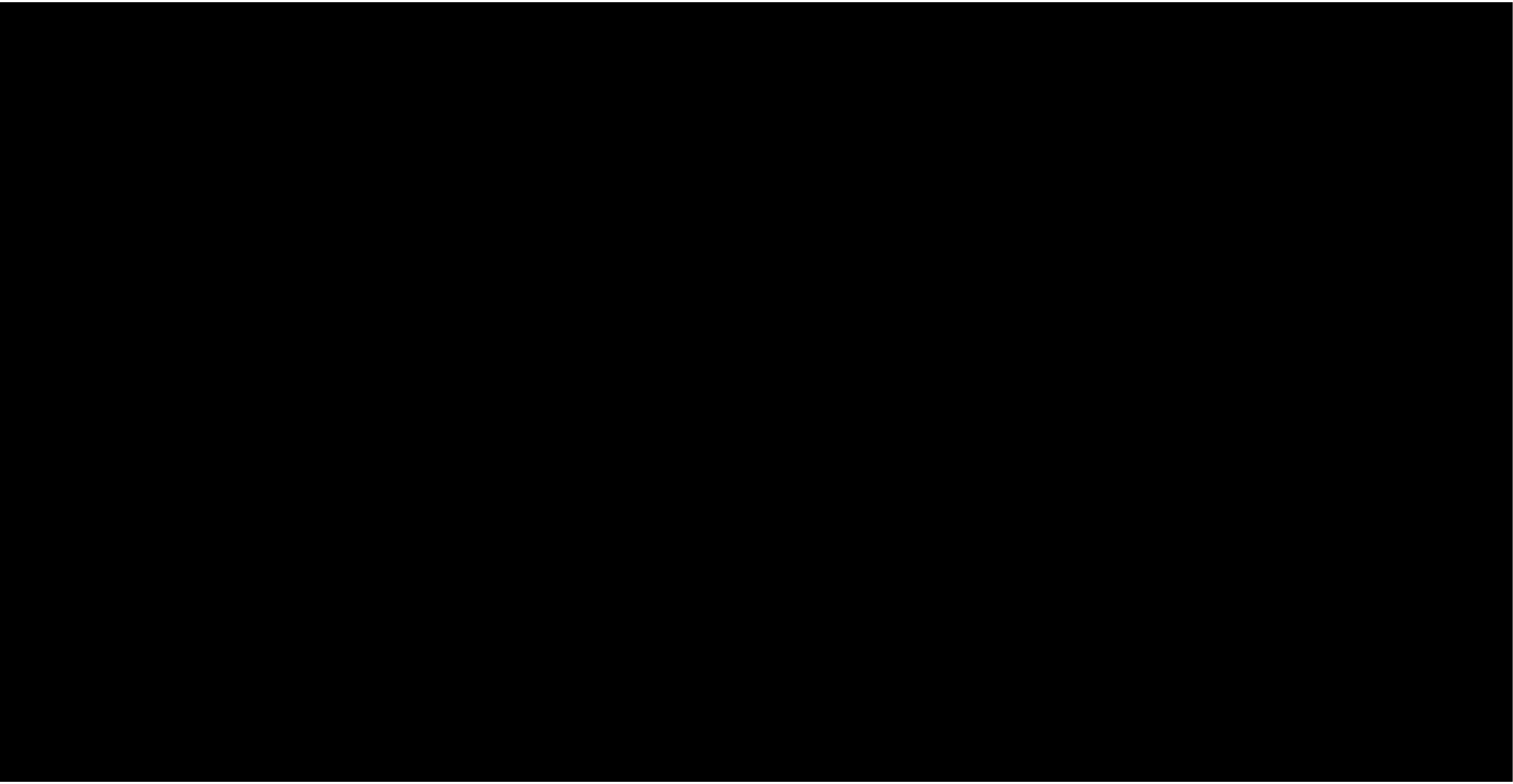
1. Cervical Compression Test:

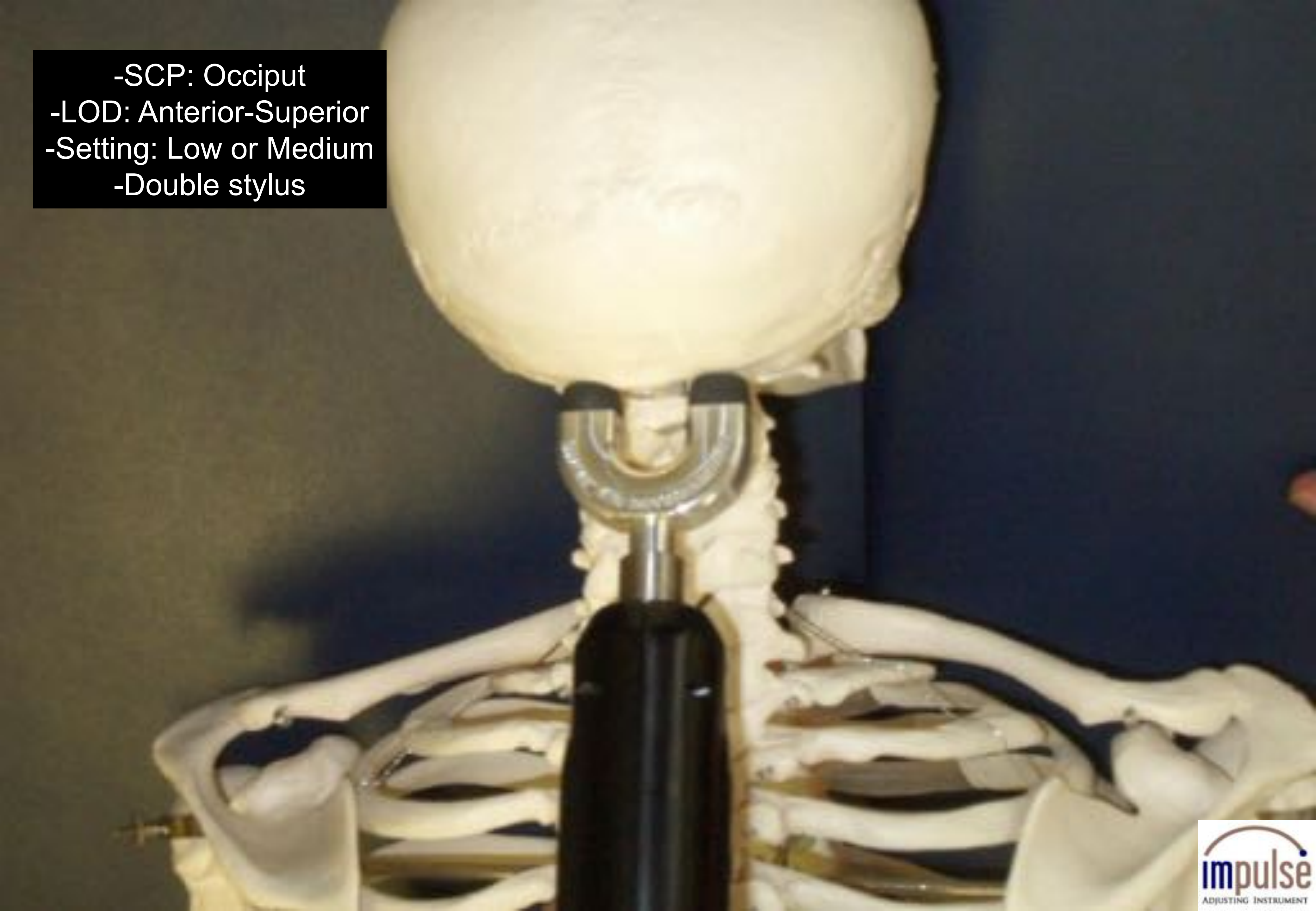
Cervical compression test:

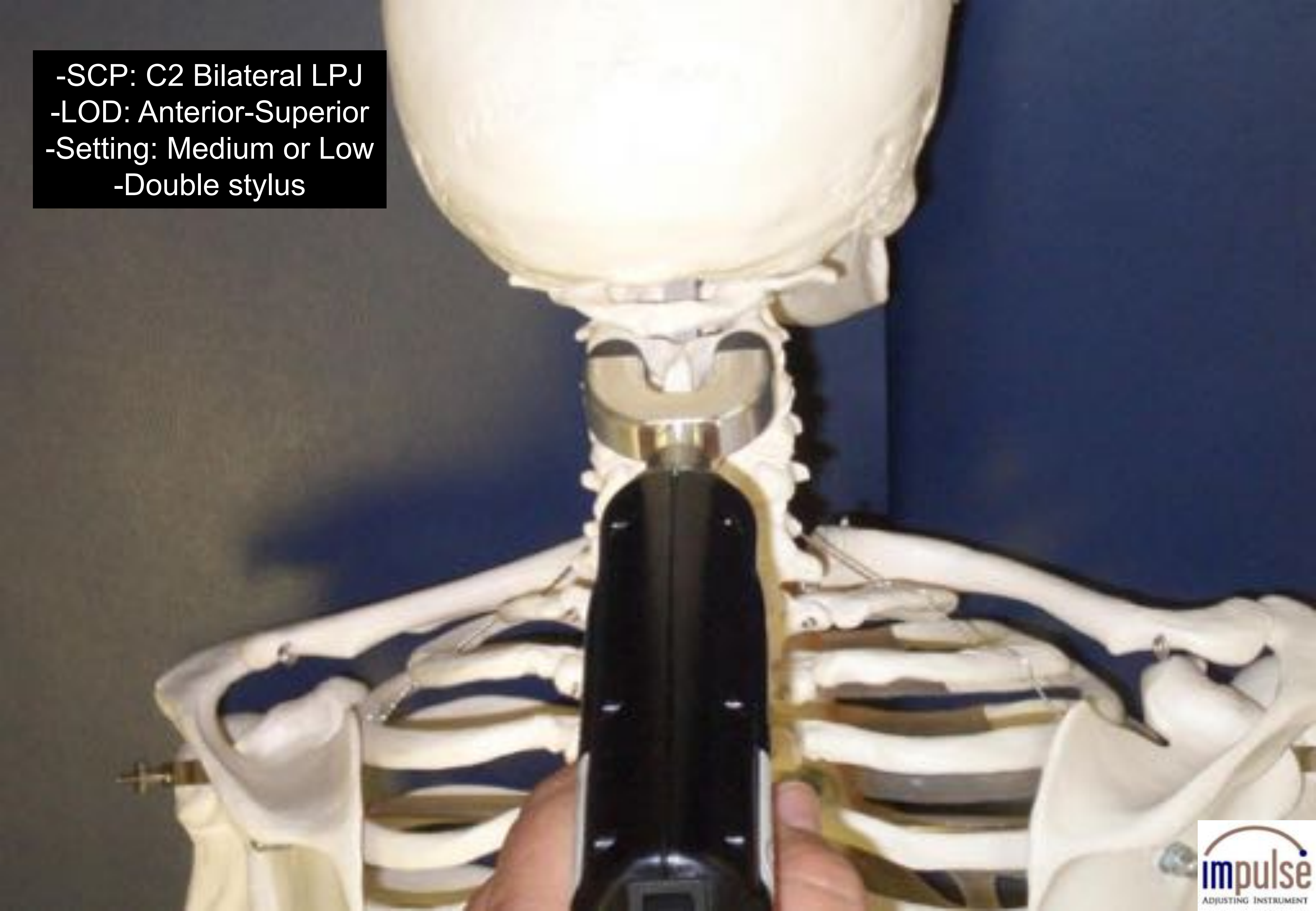
- **Patient reports pain in upper neck or skull:**

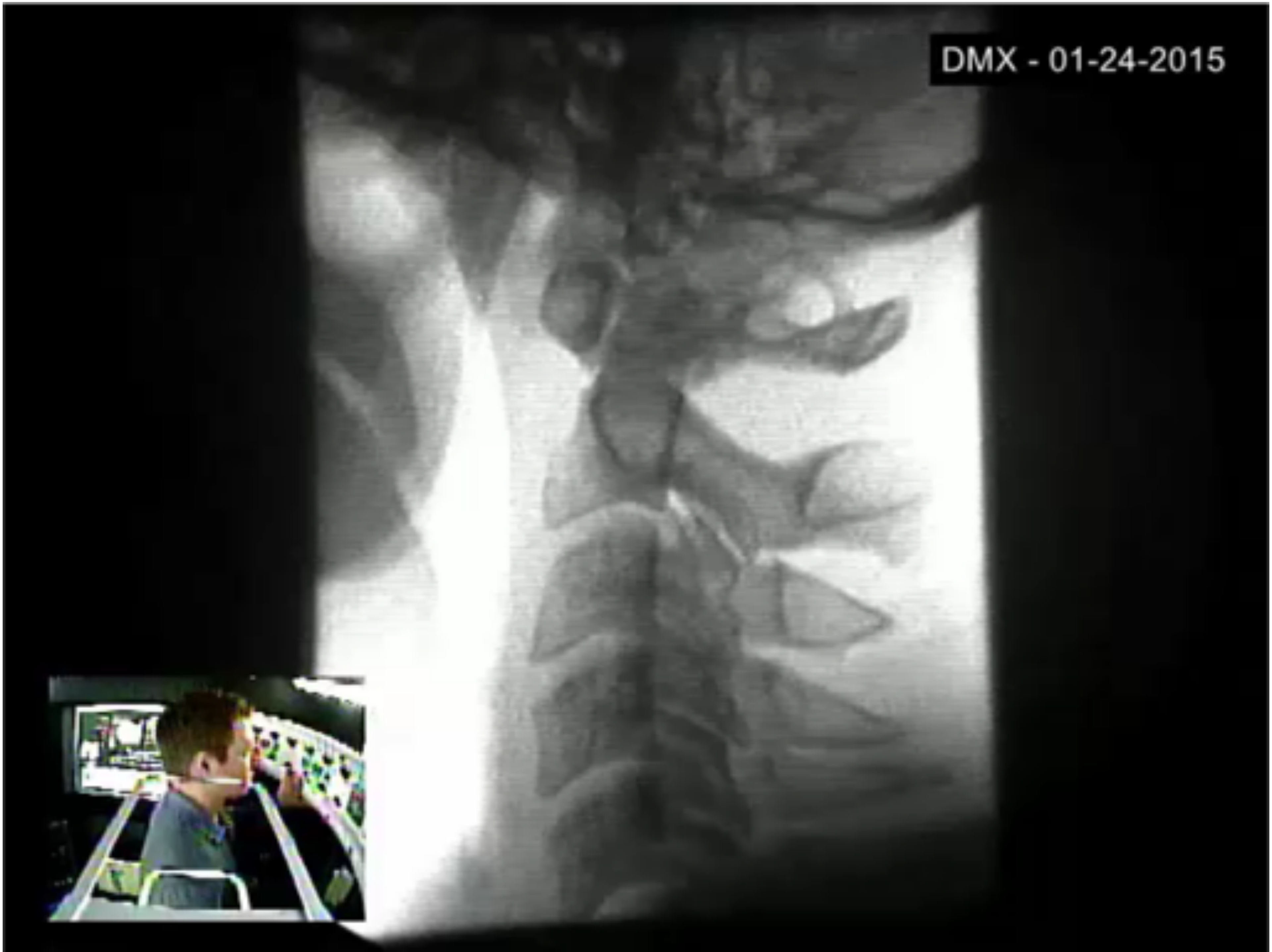
Adjust C2 and occiput with dual stylus, posterior to anterior.

- **Upper cervical spine and/or occipital pain with the cervical compression test, adjust occiput and C2 with dual stylus:**




-SCP: Occiput
-LOD: Anterior-Superior
-Setting: Low or Medium
-Double stylus
impulse
ADJUSTING INSTRUMENT


-SCP: C2 Bilateral LPJ
-LOD: Anterior-Superior
-Setting: Medium or Low
-Double stylus
impulse
ADJUSTING INSTRUMENT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