The Spine Journal 16 (2016) 1116–1123

THE SPINE JOURNAL

Basic Science

The provocative radiographic traction test for diagnosing craniocervical dissociation: a cadaveric biomechanical study and reappraisal of the pathogenesis of instability

Zachary Child, MD[a,*], Daniel Rau, MD[b], Michael J. Lee, MD[b], Randall Ching, PhD[b], Richard Bransford, MD[b], Jens Chapman, MD[b], Carlo Bellabarba, MD[b]

[a]*University of Texas Health Science Center San Antonio, Department of Orthopaedics, 7703 Floyd Curl Dr, Mail code 7774, San Antonio, TX 78229-3900*

[b]*University of Washington/Harborview Medical Center, Department of Orthopedics and Sports Medicine, Seattle, Washington, USA*

Received 8 November 2015; revised 24 February 2016; accepted 4 March 2016

Abstract

BACKGROUND CONTEXT: Craniocervical dissociation is a rare but serious condition, and missed injuries have been associated with poor neurologic outcomes and deterioration. A fluoroscopic traction test is employed to interrogate the craniocervical ligaments when clinical and imaging findings are equivocal. However, no specific protocol or known parameters with respect to traction or force applied have been established.

PURPOSE: This study sought to define the parameters of the radiographic traction test with sequential sectioning of the primary ligamentous restraints under controlled distraction of the craniocervical junction in a biomechanical model.

STUDY DESIGN: This is a cadaveric biomechanical study.

METHODS: A custom loading apparatus applied traction forces in six specimens (O-C3) and the following ligaments were sectioned: alar, tectorial membrane, and occiput-C1 capsules to simulate varying degrees of craniocervical dissociation. Traction was applied 0 to 20 lb with fluoroscopy. Digital image analysis quantified the relative displacements of C0–C1, average craniocervical excursion, and under what load could a 2-mm craniocervical displacement be reproducibly recorded.

RESULTS: A weight-distance table was produced and showed a marked loss of stability with sectioning of the ligaments and across all specimens in a similar pattern. Minimal translation was noted with sectioning of two of three ligaments in any order (<1–2 mm). All specimens exhibited a firm restraint to dissociation until the last of the three stabilizers was sectioned. Thus an “all-or-none” restraint to instability is present. All specimens failed at a weight of 5–10 lb (>2 mm).

CONCLUSIONS: The current knowledge base of craniocervical injuries is very limited. This study shows that the key restraints to craniocervical instability are the alar ligaments, tectorial membrane, and the atlantooccipital joint capsules. Dissociation requires the complete incompetence of all three. The craniocervical traction test reliably demonstrates instability and requires no more than 5–10 lb of traction to perform.

Keywords: Atlantoaxial; Atlantooccipital; Cervical; Craniocervical; Dislocation; Dissociation; Internal decapitation

FDA device/drug status: Not applicable.

Author disclosures: ***ZC:*** Nothing to disclose. ***DR:*** Nothing to disclose. ***MJL:*** Consulting: Stryker Spine (C), Depuy Synthes (B), outside the submitted work. ***RC:*** Nothing to disclose. ***RB:*** Speaking and/or Teaching Arrangements: AOSpine North America (B); Grants: Depuy Synthes (B, Paid directly to the institution/employer); Fellowship Support: AOSpine North America (E, Paid directly to the institution/employer), Depuy Synthes (E, Paid directly to the institution/employer), Omega (D, Paid directly to the institution/employer), outside the submitted work. ***JC:*** Stock Ownership: Renovis (G); Trips/Travel: AOSpine North America (B); Board of Directors: AOSpine North America: (C), outside the submitted work. ***CB:*** Speaking and/or Teaching Arrangements: AOSpine (D); Fellowship Support: AOSpine North America (E [when application is successful], Paid directly to the institution/employer), outside the submitted work.

None of the authors have any competing interests. Neither the corresponding author nor the remaining authors declare any pertinent conflicts of interest.

Source of Funding: Only internal University of Washington Department of Orthopaedics funding was used for this study.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

* Corresponding author. Department of Orthopaedic Surgery, Spine Surgery and Musculoskeletal Oncology, University of Texas Health Science Center San Antonio, 7703 Floyd Curl Drive, MSC-7774, San Antonio, TX 78229, USA. Tel.: +1 (210) 567 5125; fax +1 (210) 567 5167.

E-mail address: childz@uthscsa.edu (Z. Child)

http://dx.doi.org/10.1016/j.spinee.2016.03.057

1529-9430/

Introduction

The craniocervical ligaments, both principal and accessory, have been described in the anatomical and orthopedic literature, and craniocervical dissociation has been increasingly reported in case series suggesting that decreased mortality may be due to improved recognition [1–3]. Craniocervical, occipitocervical, and atlantooccipito dissociation are all synonymous terms to describe a complete lack of ligamentous stability between the skull (cranium) and the cervical spine. Internal decapitation has been popularized in the media to describe the condition. Spine consultation for patients with potential craniocervical dissociation where the mechanisms, symptoms, clinical examination, and imaging findings are suggestive but equivocal pose a diagnostic challenge. In these instances, a fluoroscopic traction test may be employed to interrogate the craniocervical ligaments. However, no specific protocol or known parameters for traction weights have been established. Missed craniocervical injuries have been associated with poor neurologic outcomes and deterioration [1].

In conjunction with the pioneering biomechanical studies by Dvorak et al. [4,5], much has been learned of the relationship between the structural ligaments and the traumatic instability of the craniocervical region [4–7]. Perhaps the most detailed classic studies of the craniocervical ligaments were performed by such masters of anatomy as Humphrey and especially Henry Morris more than a century ago. This articulation was nicely reviewed by Cave in 1933. But a review of the pathoanatomy of traumatic craniocervical dissociation in the contemporary literature is lacking [8–10]. The Harborview Classification of Craniocervical Injuries (see Table 1) established a role for the manual traction test in its stage 2 injuries where baseline craniocervical joint alignment (C0–C1) is within 2 mm but magnetic resonance imaging suggests injury to the osteoligamentous structures. However, no specific protocol or known parameters for traction weights have been established.

Harborview Medical Center has the largest running case series of craniocervical dissociation in the spine literature [1]. Our institution (Harborview Medical Center) is currently looking at a series of 49 patients with documented craniocervical dissociation (unpublished data) who have magnetic resonance imaging (MRI) to determine the status of the craniocervical ligaments. This study will complement the traction test above and has provided guidance for the sequence and occurrence of ligamentous instability. The hypothesis of the current study is that there is a defined maximum weight that would show sufficient sensitivity and specificity to yield a positive test. Defining this weight limit would enable practitioners to better diagnose an unstable craniocervical interval (ie, all subjects demonstrated greater than 2 mm of distraction at “X” lb, therefore testing need not exceed “Y” lb). Furthermore, sectioning of ligaments sequentially would show the relative value of each ligament in maintaining the structural integrity of the craniocervical interval. This study seeks to define the parameters of a positive traction test with sequential sectioning of the primary ligamentous restraints under controlled distraction of the craniocervical junction. Simply, this study aims to find how much force is required to test the patient and what structures keep the cranium attached to the spine.

Table 1
Harborview classification of craniocervical injuries

Stage	Description of injury
1	Magnetic resonance imaging of injury to craniocervical osteoligamentous stabilizers. Craniocervical alignment within 2 mm of normal, distraction of 2 mm or less on provocative traction radiographs
2	Magnetic resonance imaging of injury to craniocervical osteoligamentous stabilizers. Craniocervical alignment within 2 mm of normal, distraction of more than 2 mm on provocative traction radiographs
3	Craniocervical malalignment of more than 2 mm on static imaging studies

Methods

This study was performed at the University of Washington Applied Biomechanics Laboratory. Six fresh frozen (unembalmed) human head-neck specimens were obtained from an approved biospecimen provider (American Association of Tissue Banks). All tissues were stored frozen (at −20°C) until use and handled in accordance with the University of Washington’s procedures for biohazard control (University of Washington Biosafety Manual). For assessment of the ligamentous integrity and displacement of the atlantooccipital joint, each cadaver specimen (skull to C5) was prepared with the cervical vertebrae C2–C5 potted in a polymethyl methacrylate base. The cervical spine underwent gross dissection to remove the soft tissues (musculature) while preserving the osteoligamentous structures (vertebrae, ligaments, and intervertebral discs) and insertion of metal screws and stainless steel wire reinforcement of the C2–C5 vertebral bodies and processes to strengthen the potted base. Care was taken to ensure that only the inferior half of the C2 vertebra was embedded in the urethane resin base potting compound, and that the C0–C2 segments were exposed and free to articulate.

The cranium was sectioned above the temporalis fossa leaving adequate bone to accommodate Mayfield traction three-point tongs or similar traction fixture. The mandible was removed to provide improved C0–C2 imaging, and all central neural elements were removed leaving the principle ligaments under study intact. Radiographic fiducial (indicator) markers were affixed to C0–C1–C2 vertebrae of the specimen in the mid-sagittal plane along with a radiopaque scale to facilitate digital image analysis of fluoroscopic images to establish the relative distraction across C0–C1–C2. A custom bench-top test apparatus was used to apply traction