Understanding The Biomechanics Of The Craniocervical Junction

...And When Do I Intervene

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No Disclosures
Normal Load Transfer Through the CVJ

1.5 y

2 y

4 y

6 y

8 y

11 y
Traditional Concepts of Occipitocervical Biomechanics

- Determinants of O-C1 stability
  - Cup-shaped joints
  - Capsular ligaments
  - Tectorial Membrane
  - Ant. + post. A-O memb.
  - Alar ligament
  - Apical ligaments

- Determinants of C1-2 stability
  - Transverse ligament
  - Odontoid integrity
  - Alar ligaments
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“The Team”

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What is the Finite Element Method?

- A numerical solution technique for discretizing a larger geometrical problem into smaller pieces called finite elements.

- Robust FEMs give an accurate representation of complex geometrical structures that contain dissimilar material properties by discretizing the larger structure into numerous smaller pieces for evaluation.

- Recent advances in computational power have allowed researchers to use FEMs to examine the biomechanical behaviors of a wide variety of skeletal structures, including the spine.

- It’s important that a FEM must be validated with cadaveric biomechanical test results.
The FE Method In CCJ Biomechanics

Creation: Method

CT Scan
Segment CT Data
Generate Surface
Mesh Surface
Material Properties
Boundary Conditions
Perform FEA
Analyze Results
The FE Method In CCJ Biomechanics

Creation OF Material Properties and Boundary Conditions

- LIGAMENTS – TENSION-ONLY SPRINGS WITH LINEAR PROPERITES
- ADULT LIGAMENT (50%, 25%, 10%)
- SOFT TISSUE – MOONEY-RIVLIN AND NEO-HOOKEAN
- MESH CONVERGENCE

- BONES- RIGID BODIES
- C0 - C1 UNCONSTRAINED
- C2 - C3 FIXED
- CONTACT ENFORCED USING PENALTY METHOD
- ±0.1 – 1.0 NM TORQUE (C0)
Initial Validation: Pediatric

Pediatric Validation: Normal

Intact Flexion/Extension
- 13mo
- 10yo
- 14yo
- Luck 5-22mo
- Luck 6-12yo
- Luck 14-18yo

Adult Validation: Normal

Intact Flexion/Extension
- Model 1
- Model 2
- Model 3
- Osth et al. FE
- Puttlitz FE
- Panjabi

Model 1 = 29 YO, Model 2 = 59 YO and Model 3 =64 YO
Ligamentous Injury Scenarios: Isolated and Combination

- Intact
- OACL stiffness reduction
- TL removal
- TM removal
- AL removal
- TM + TL
- OACL + TL
- OACL + TM
- OACL + TM + TL
- OACL + AL
Pediatric OACL + TL Injury

Normal

Injured

13 Month F

10 Year F

14 Year F
Pediatric AAACL Injury – Axial Rotation

Normal

Injured
OACL injury simulation (Averaged 10, 14, 29, 59 and 64 YO)

A) Flexion, B) Extension, C) Axial and D) Lateral. *indicates significance # indicates 14 YO model run was not included
AACL Preliminary Results (10, 15, 29, 59 and 64 YO)

A) Flexion, B) Extension, C) Axial and D) Lateral Bending.
Conclusions

• OACLs are the primary stabilizers of the OA joint*
• AACLs and the TL are the primary stabilizers of the AA joint
• TM and AL do not play a major role in either joint
• Within the FE model, facet geometry plays a role in CCJ stability

*Phuntsok R, Ellis B, Herron M, Provost C, Dailey A, Brockmeyer DL: The occipitoatlantal capsular ligaments are the primary stabilizers of the occipitoatlantal joint in the craniocervical junction: a finite element analysis. JNS:Spine , In final review
Clinical Implications: AOD

CVJ: Condylar-C1 Interval (CCI)

ATLANTO-OCCIPITAL DISLOCATION:
PART 1—NORMAL OCCIPITAL CONDYLE-C1 INTERVAL IN 89 CHILDREN
Dachling Pang, M.D., William R. Nemzek, M.D., John Zovickian, M.D.

Neurosurgery, Volume 61, Issue 3, 1 September 2007, Pages 514-521,

ATLANTO-OCCIPITAL DISLOCATION—
PART 2: THE CLINICAL USE OF (OCCIPITAL) CONDYLE−C1 INTERVAL,
COMPARISON WITH OTHER DIAGNOSTIC METHODS, AND THE MANIFESTATION,
MANAGEMENT, AND OUTCOME OF ATLANTO-OCCIPITAL DISLOCATION IN
CHILDREN
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Neurosurgery, Volume 61, Issue 5, 1 November 2007, Pages 995-1015,
Clinical Implications: AOD

5 year-old girl, MVA
4 y/o Restrained Passenger MVA
O-C1-C2 Combination Injury

Not uncommon
Flexion-distraction mechanism
Requires O-C2 fusion at a minimum
2 y/o Fell Down The Stairs
C2 Synchondrosis Fracture

Brace vs. Halo?
Surgery only for progressive deformity
When Do I Intervene at the CVJ:

O-C1
1) Compromise of the bony supportive structures
2) Compromise of the OACLs

C1-2
1) Lack of odontoid integrity
2) Lack of C1 ring integrity
3) Lack of TL integrity
4) Compromise of the AACLs
Supportive Imaging:

1) C-spine x-ray (Neutral, Flex-Ex)
2) Thin cut CT with 2-D recons
3) MRI (T1, T2, STIR)

Gold standard for instability:
1) Flex-Ex CT
When Do I Intervene at the CVJ:

1) Congenital
   Instability on dynamic imaging
   Down vs. non-Down syndrome
   C1 Hemirings/dysplasias
   Significant sagittal deformity
   Vertical instability
   Neuro deficit/compression

2) Trauma
   CCI > 4.0 mm (relative)
   Failed halo after synchondrosisis fx

3) Tumor
   Significant C2/condyle removal (far lateral)

4) Post-Chiari decompression

5) Post-odontoid resection
Thank You For Your Attention