Analysis of Computational Neck Models

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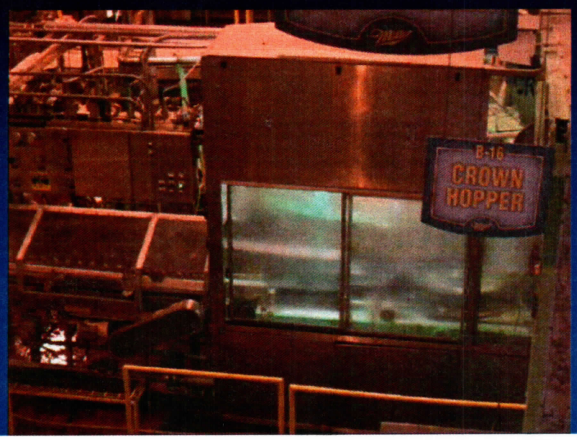
Kinematics of bottlecaps through bifurcation



Objectives

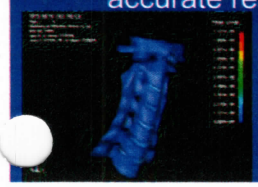
- Determine the current status of detailed computational models of the neck
  - Component models
  - Full body models
- Develop a modeling strategy for studying carotid artery injury mechanisms in lateral impacts

Methods

- Literature review of computational models of the neck in publicly available sources
- Model features and validation test results from journal articles and publications
- Usefulness of model for neck response in lateral impacts gauged from available information
- Models recommended that will offer the best kinematic response of neck

Component Neck Models

- Detailed design of local neck geometry and interactions
- Computationally more efficient then full body models
- Difficult to setup positioning of occupant in vehicle interior with accurate restraint conditions


Halldin


Duke


Van der Horst

Component Neck Models

Author	Program	# Elements	Loading Conditions	Advantages	Disadvantages
Nitsche	PAM-CRASH	1852 Solid; 86 Membrane	Front; Lateral; Axial	Good validation results	No musculature; No full body
Yang	PAM-CRASH	11,498 Solid; 3071 Shell	Front; Rear; Axial	Detailed geometry; Passive neck muscles	More validation required; Full body not complete
Deng	LS-DYNA	Unknown	Frontal	Detailed geometry; Active neck muscles	More validation required; No full body
Chancey	LS-DYNA	639 Rigid; 448 Deform	Axial	Active neck muscles; Good axial validation	Only axial impact; No full body
Van der Horst	MADYMO	N/A	Front; Lateral; Rear	Good validation results; Active neck muscles	No FE techniques for better local response

Full Body Models

- Duplicate positioning of occupant in vehicle interior
- Replicate response of occupant in lateral impact
- Extract kinematic response from model for use in local soft tissue model of neck

Full Body Models

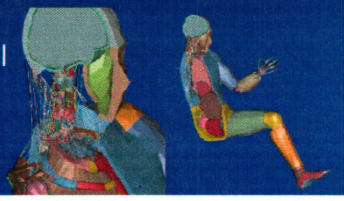
Author	Program	# Elements	Loading Conditions	Advantages	Disadvantages
Lizee	RADIOSS	10,000	Front; Lateral; Rear	Efficient; Global validation	Crude geometry; No neck musculature
Iwamoto	LS-DYNA	83,500	Front; Lateral; Rear	Thorax/spine validation for lateral; Active neck musculature	Lacks overall validation
Ruan	PAM-CRASH	119,000	Front; Lateral; Rear	Detailed neck with remodeled facet joints and ligaments	Lacks overall validation; No neck musculature
Van der Horst	MADYMO	N/A	Front; Lateral; Rear	Good lateral validation; Active neck muscles	No FE techniques for better local response

MADYMO Detailed Neck

- Published by De Jager, Van der Horst, and Meijer
- Refined geometry of vertebral bodies
- Active and passive muscle effects
- Widely validated, including some side impact with good correlation
- No FE techniques
- Integrated into 50th percentile full body model

THUMS Neck

- Published by Iwamoto
- Accurate FE geometry
- Active and passive muscle effects
- Thorax and spine segments have been validated for lateral impacts
- Integrated into 50th percentile full body model
- No published overall model validation to lateral impacts



Neck Tissues

- No component or full body model has soft tissues of the neck modeled
- Soft tissue = important for lateral impacts
- If present, muscle elements do not have contact characteristics, only tensile properties
- Most finely meshed component or full body model is too large for meaningful FE model of carotid artery

Investigation of the effects of NaCl and Miller-OH on soft tissues of the face

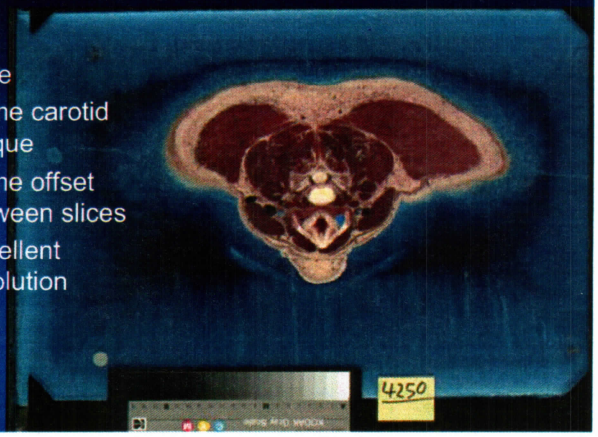
Effects of anthropometry and gender on sports equipment impact

Approach (in progress) for creating FE model of carotid

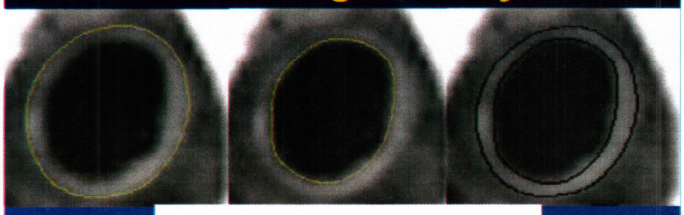
- Visible human data for soft tissue geometry
  - Exceeds accuracy and detail of MRI/CT
  - Compatible with most human body models which were also created using this dataset

Visible human data

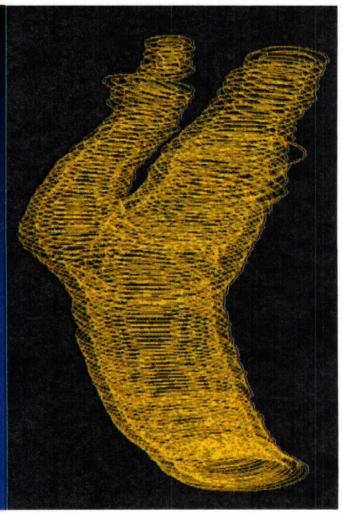
- Male
- Some carotid plaque
- Some offset between slices
- Excellent resolution



Carotid geometry



Draft 3-D representation of carotid



Suggested measurements

- Load in belt
- Pressure in carotid (Millar)
- Kinematic measurements
- Measures of neck extension – outer skin above carotid – correlate to carotid strain?
- Tensile loading mechanism important?

Suggested testing

- Stiffness of tissues between bony structure and skin of neck
- Tissue level material testing
  - QLV? Step and relaxation? Rate effects?
  - Lee, Haut (80's, GM) – strain rate no effect on peak load or stiffness in jugular – axial
  - Monson et al (2003) – ASME – human carotid no effect over 4 orders of magnitude

Testing Methodologies

- (from literature on testing arteries) – as suggestion
  - Loop tests
  - Burst tests
  - Axial tests

Approach

- SIMON-esque approach to evaluate carotid injury.
- Anatomical FE landmarks on a whole body model to drive some component model containing the carotid.
- A more detailed model of carotid geometry and surrounding bony/soft tissue geometry would then be used to evaluate carotid injury.
- Allow one to incorporate the benefits of modeling at a finer level for specific injury mechanisms, but still keep the usefulness of a whole body simulation.

The End

- Thank you!
- Questions?