Multi-center analysis of CIREN occupant lumbar bone mineral density and correlation with age and fracture incidence

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Last Year’s Goals

• Lumbar BMD of 281 WFU occupants (109 M, 172 F) was quantified using phantom-less CT method
  – Of those classified as osteopenic (<145 mg/cc) using this technique
    • 64% are undiagnosed in CIREN
    • 36% are correctly classified in CIREN

Weaver, Traffic Injury Prevention, AAAM, 2015.
Current Goals of Study

• Quantify lumbar BMD of 873 CIREN occupants (372 M, 501F) from 8 centers using phantom-less CT method
  – 873 CT scans obtained from CIREN database
    • 8 centers: Wake Forest, UVA/Fairfax, UAB, MCW, U of Maryland/Baltimore, Seattle, Michigan, San Diego
  – Additional CT scans requested from current CIREN centers
BMD Analysis
Phantom-less vBMD Analysis Workflow

Validate Phantom-less vBMD Technique
Pilot data: DXA & QCT Measures (50 subjects; 17M, 33F)

Quantify vBMD in CIREN Occupants
Collect vBMD & tissue measures for calibration to mg/cc

Correlate vBMD with CIREN Data
Relate vBMD to CIREN occupant demographics, comorbidities, injuries

[Images of medical scans and tissue samples]
Lumbar Spine BMD Analysis of Pilot & CIREN CT Scans
ROIs for BMD Calibration from HU to mg/cc

**Phantom calibration measures**

Port 2: 0 mg/cc CaHA  
Port 3: 75 mg/cc CaHA  
Port 4: 150 mg/cc CaHA

**Fat-muscle calibration measures**

Muscle: right psoas  
Fat: subcutaneous, anterior

INTable Calibration Phantom  
http://www.image-analysis.com/intable_phantom
Phantom Calibration Method

Phantom calibration technique applied to each pilot subject scan:
Linear regression fit: [0, 75, 150] mg/cc CaHA vs Ports 2-4 ROI measures

![Graph showing Phantom Calibration Method](image)

- Equation: \( y = 0.90x + 40.16 \)
- \( R^2 = 1.00 \)
Fat-Muscle Calibration Method

Fat-muscle calibration technique applied to each pilot subject scan:
Assumed ground truth values: Fat = -69, Muscle = 77 mg/cc CaHA
Linear regression fit: [-69 77] mg/cc CaHA vs [Fat Muscle] ROI measures
Calibration Method Comparison

- Pilot dataset shows Fat-Muscle Calibration ≈ Phantom Calibration
- Fat-Muscle Calibration applied to phantom-less CIREN scans

\[
y = 0.69 + 1.00x \\
R^2 = 0.87 \\
p = <0.0001
\]

Mean Lumbar BMD (mg/cc CaHA)
CT-based Predictive mg/cc Threshold for Osteopenia

- DXA/CT, 50 subject pilot data

145 mg/cc Maximum Sensitivity (ROC Analysis)

Mean Lumbar BMD (mg/cc CaHa)

- Normal T-score >= -1
- Osteopenia or Osteoporosis T-score < -1

L1-L4 T-Score from DXA
2015 CIREN Study Population

- 873 occupants (372 M, 501 F) across 8 centers
- Abdominal CT
- Ages 16+

CIREN Comorbidities

Diagnosed osteopenia/osteoporosis
92 subjects

No documented osteopenia/osteoporosis
781 subjects

10.5%
89.5%
CIREN Truth Table of Bone Quality: Documented Comorbidities vs CT-Predicted vBMD

>= 145 mg/cc - Normal

< 145 mg/cc - Osteopenia

Mean lumbar BMD (mg/cc CaHA)

39 Misclassified in CIREN?

81 Undiagnosed osteopenia?

53 Osteopenia

TN 700, Normal

FP

FN
**CIREN Subjects**

**Documented Comorbidity in CIREN Database?**

- No osteopenia/osteoporosis comorbidity
- Osteopenia/osteoporosis comorbidity

**Female:**
- $vBMD = 298.2 - 1.99(age)$

**Male:**
- $vBMD = 281.8 - 1.77(age)$

**145 mg/cc Threshold for Osteopenia**

**Female:**
- $vBMD = 295.6 - 1.974(age)$

**Male:**
- $vBMD = 280.7 - 1.737(age)$

- **34F, vBMD=110 mg/cc**
  - L3-L4, calcaneous, patella fxs

- **44M, vBMD=135 mg/cc**
  - L1, L5, T12, clavicle fx

- **44F, vBMD=139 mg/cc**
  - L1-L5, 7 rib, 2 facial fx

- **81M, vBMD=302 mg/cc**
  - 9 rib, sternum, hand, pelvic, patella, tibia, fibular, femur fx – no spine fxs

- **40M, vBMD=118 mg/cc**
  - Paraplegic; fibula, femur, tibia fx
Significantly Higher # Rib/Sternum Fractures in CIREN Occupants with vBMD < 145 mg/cc

- 2.3 fractures
- 4.4 fractures
- p-value = 0.00001

>= 145 mg/cc - Normal
< 145 mg/cc - Osteopenia
Greater proportion of occupants with <145 mg/cc BMD sustained thoracolumbar, lumbar, & thoracic vertebral body fx
Summary & Conclusions

Phantom-less CT BMD Estimation Technique

Osteopenia indicated for lumbar BMD<145 mg/cc
- Associated with increased # rib/sternum fxs
- Associated with a greater incidence of thoracolumbar, thoracic, and lumbar spine fxs
- Of those classified as osteopenic using this technique
  - 60% are undiagnosed in CIREN
  - 40% are correctly classified in CIREN

Technique useful for osteopenia/osteoporosis classification of CIREN occupants & other prospective/retrospective BMD studies

Center for Injury Biomechanics

Wake Forest School of Medicine

Virginia Tech
Ongoing Research

• **Increase sample size further** by collecting non-injury CTs that are not currently in the database from CIREN centers

• **Investigate height, weight, and BMI correlation with lumbar vBMD in larger sample**
  – Poor correlation in current data; contrasts positive correlations (BMD vs weight/BMI) reported in **larger studies** (Felson, *et al.*, 1993; Reid, 2002)

• **Goal: Measure lumbar vBMD in 1000+ CIREN occupants for correlation with age, fx incidence, height, weight, & crash conditions**
Acknowledgments

Wake Forest School of Medicine Translational Science Institute
Wake Forest University Translational Science Center

Thank you to our committed collaborators!

Frank Pintar, Dale Halloway

Chris Michetti, Jeff Crandall, Thomas Hartka

Russell Griffin, Shannon Carroll

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