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

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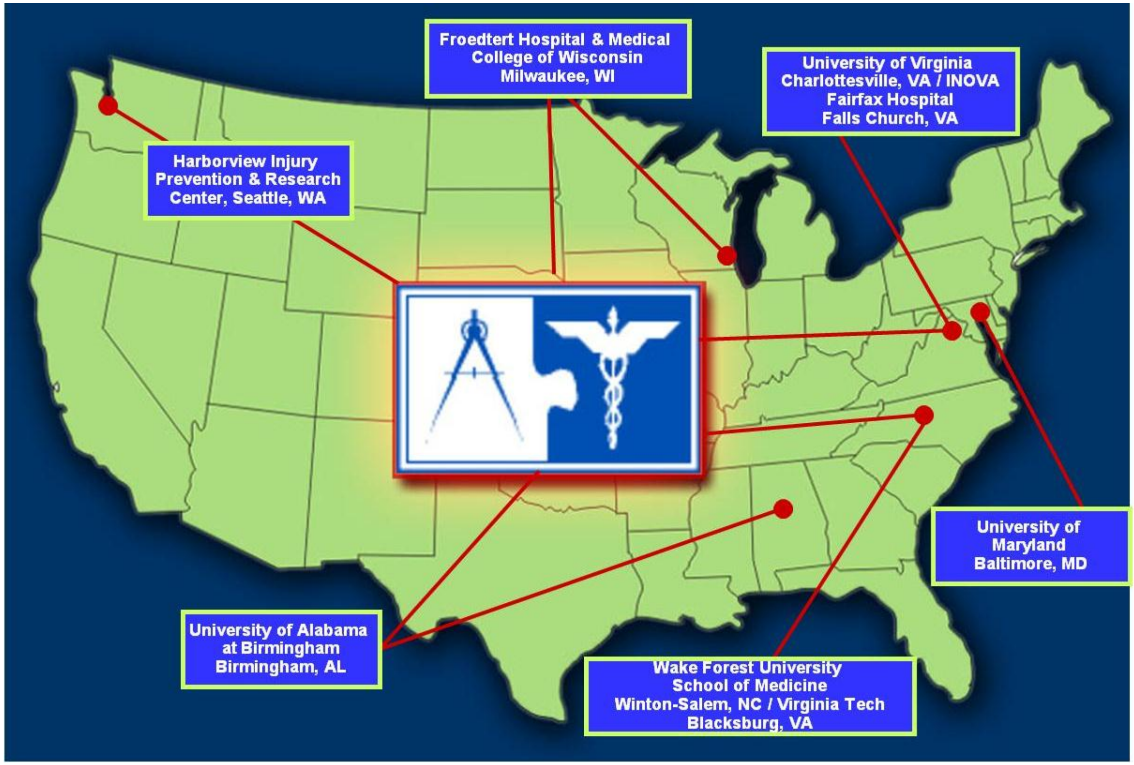
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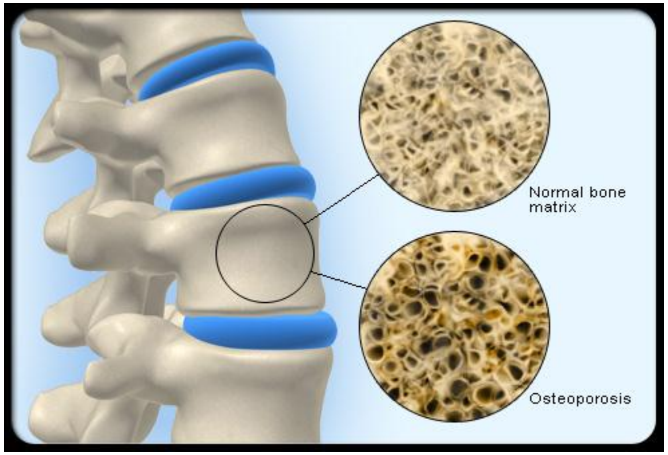
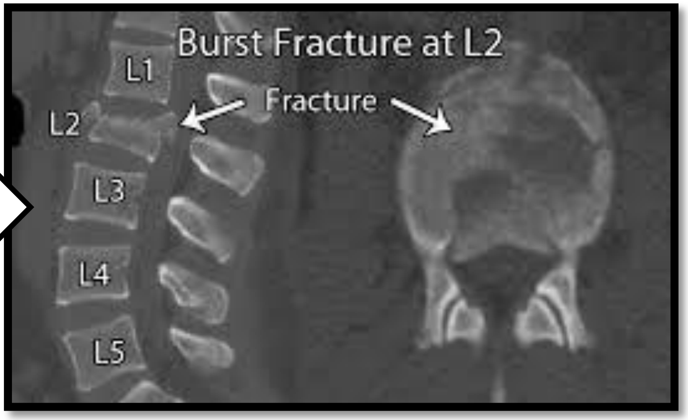

Normal bone matrix
Osteoporosis

Occupant Demographics (i.e. Age)

Osteopenia/ Osteoporosis (BMD)

Crash Characteristics

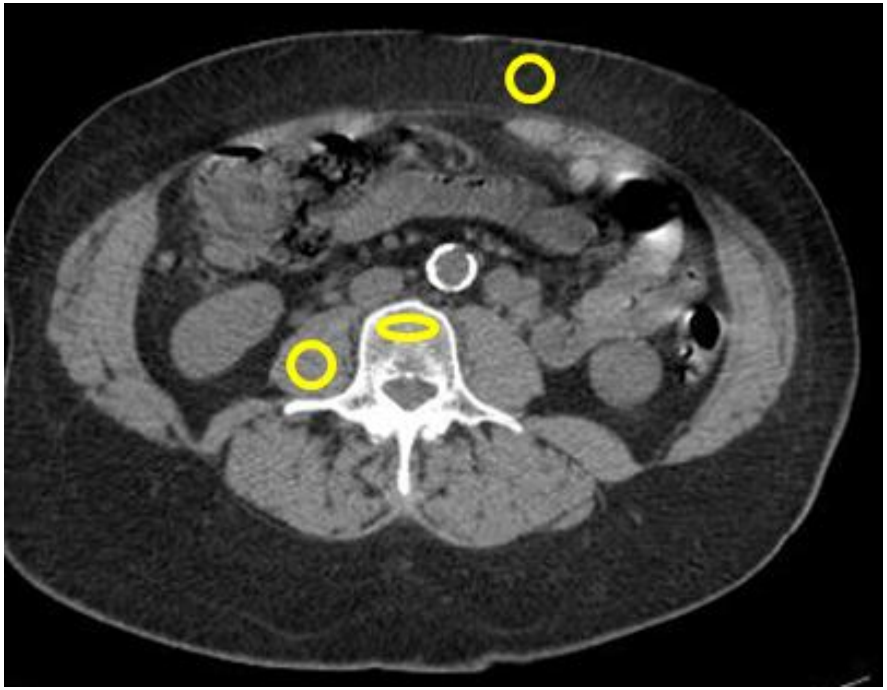
Occupant Contacts


Burst Fracture at L2
L1
L2
Fracture
L3
L4
L5

Injury Causation Investigation

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

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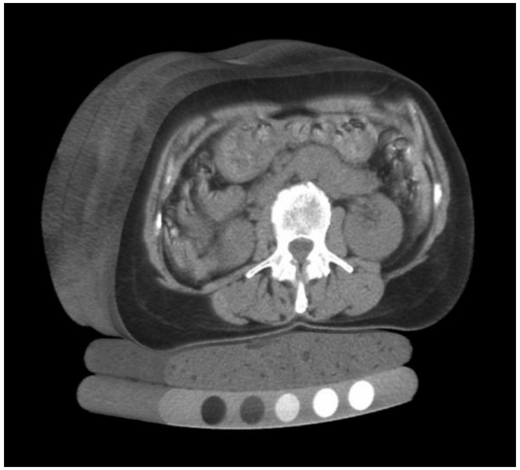
BMD Analysis

Phantom-less vBMD Analysis Workflow

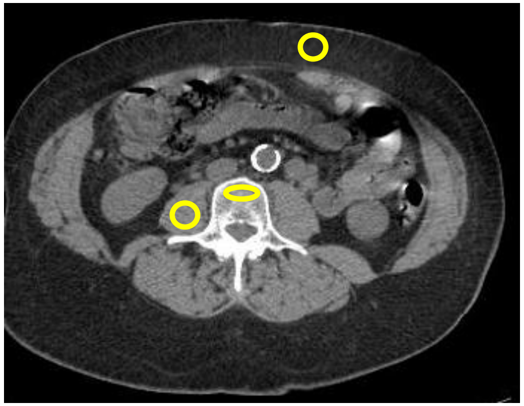
Validate Phantom-less vBMD Technique

Pilot data:
DXA & QCT Measures
(50 subjects; 17M, 33F)



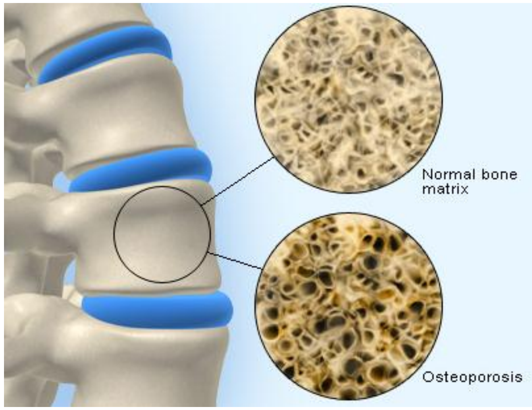
Quantify vBMD in CIREN Occupants

Collect vBMD & tissue measures for calibration to mg/cc

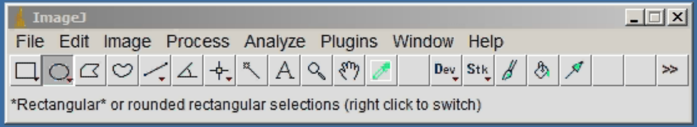


Correlate vBMD with CIREN Data

Relate vBMD to CIREN occupant demographics, comorbidities, injuries



Lumbar Spine BMD Analysis of Pilot & CIREN CT Scans


ImageJ
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Rectangular or rounded rectangular selections (right click to switch)

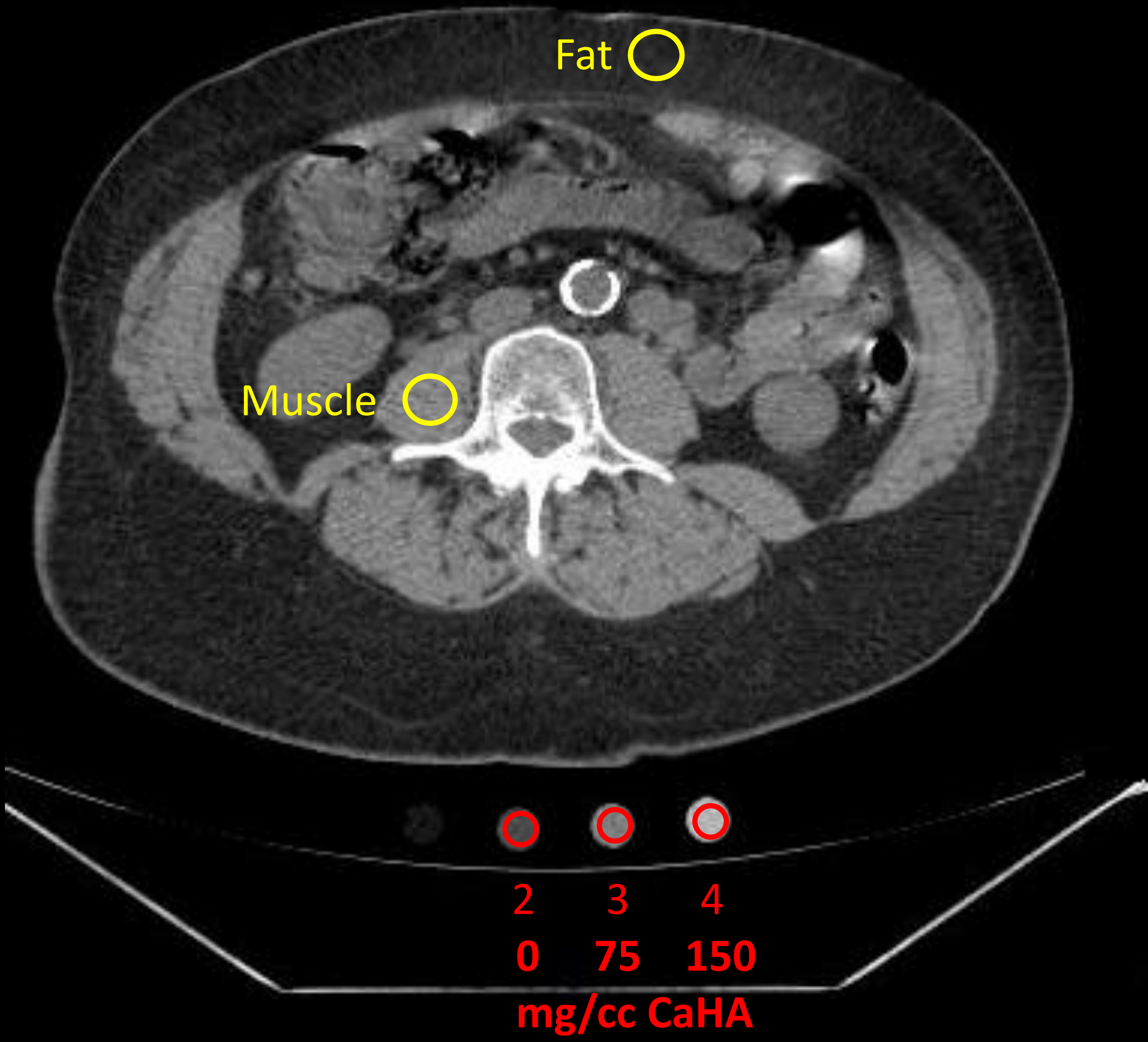
ROIs for BMD Calibration from HU to mg/cc

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


Fat
Muscle
2
3
4
0
75
150
mg/cc CaHA

INTable Calibration Phantom

http://www.image-analysis.com/intable_phantom

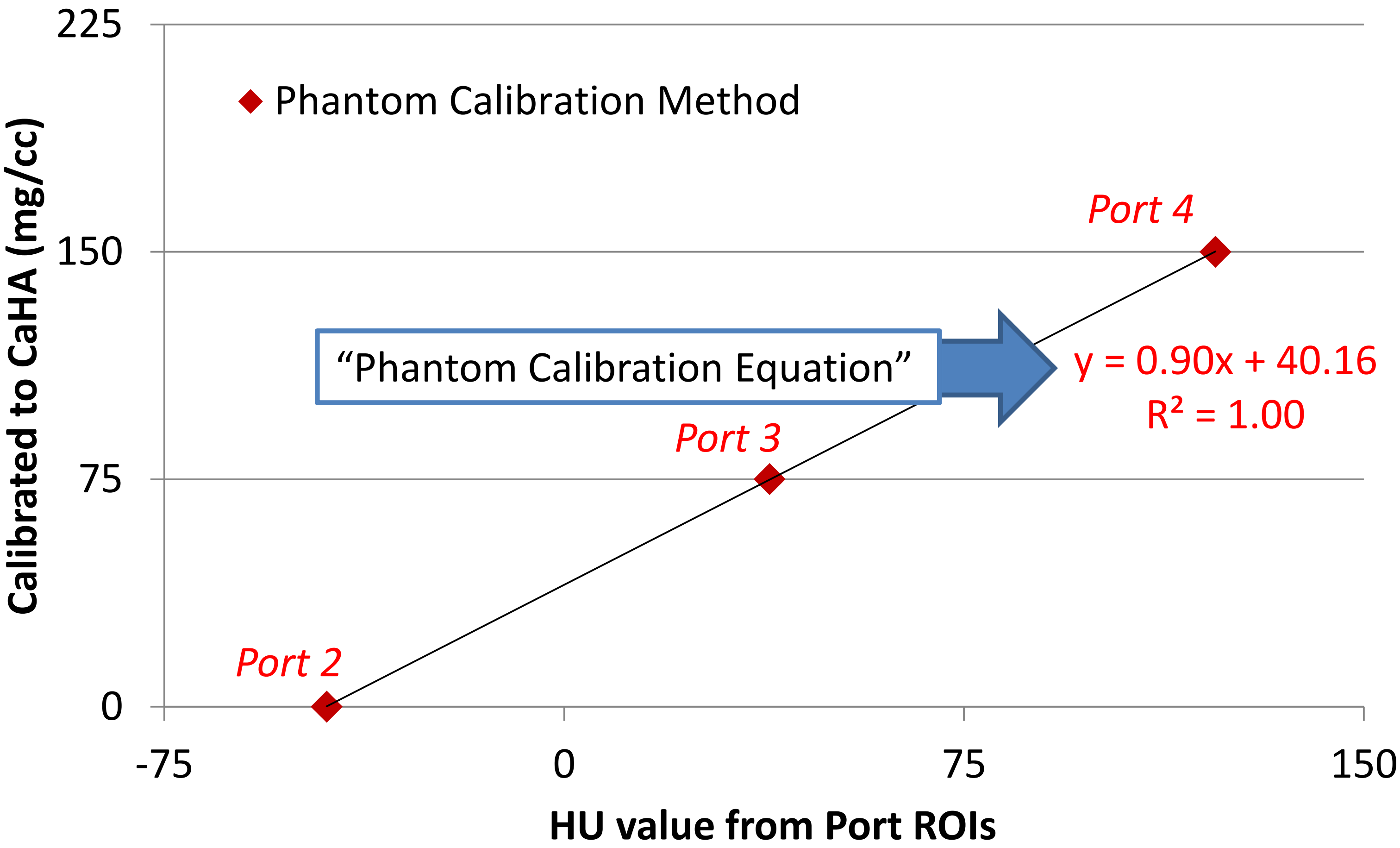
Phantom Calibration Method

INTable Calibration Phantom

0
75
150
mg/cc CaHA

Phantom calibration technique applied to each pilot subject scan:

Linear regression fit: [0, 75, 150] mg/cc CaHA *vs* Ports 2-4 ROI measures

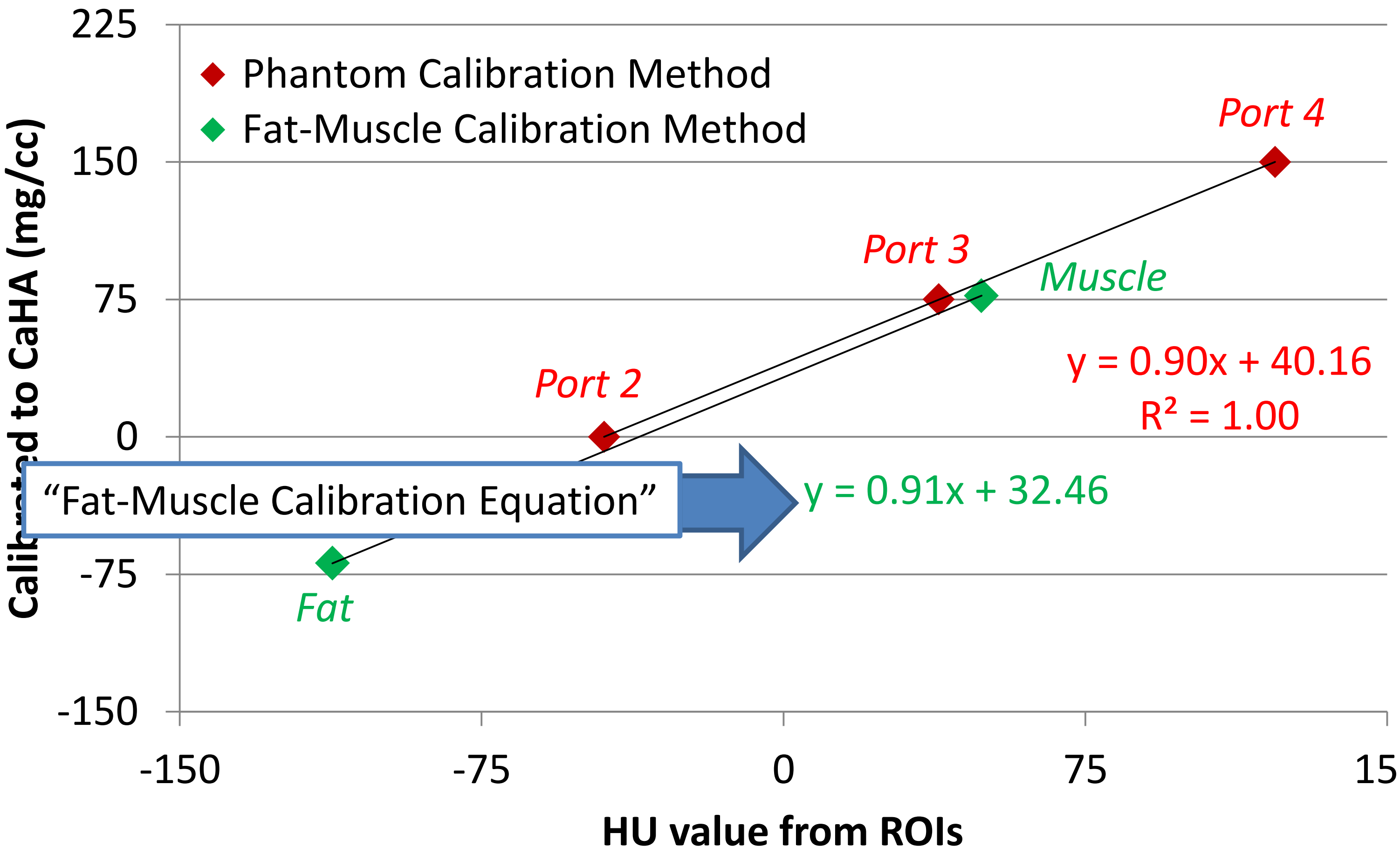


Fat-Muscle Calibration Method

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

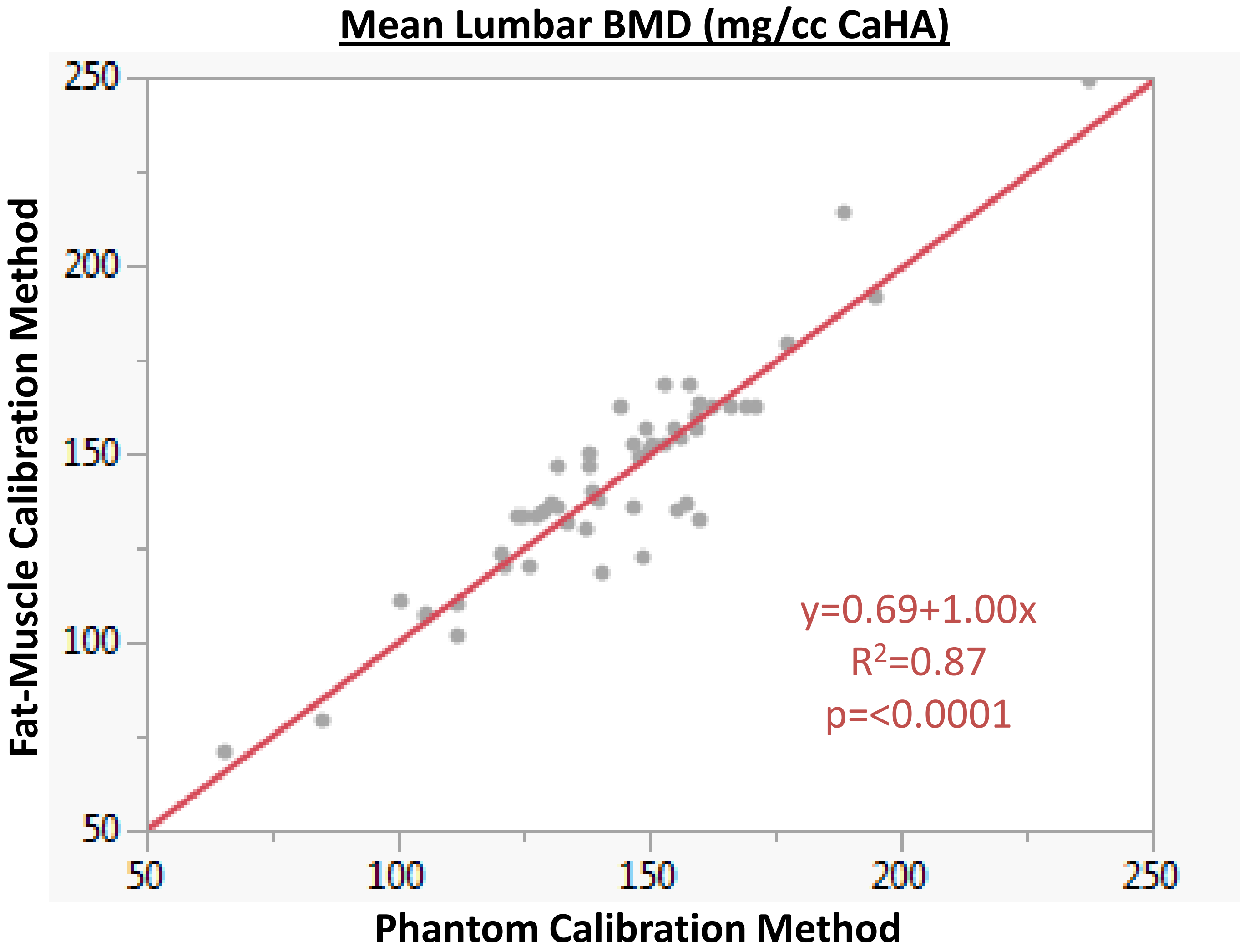


“Fat-Muscle Calibration Equation”

$y = 0.91x + 32.46$

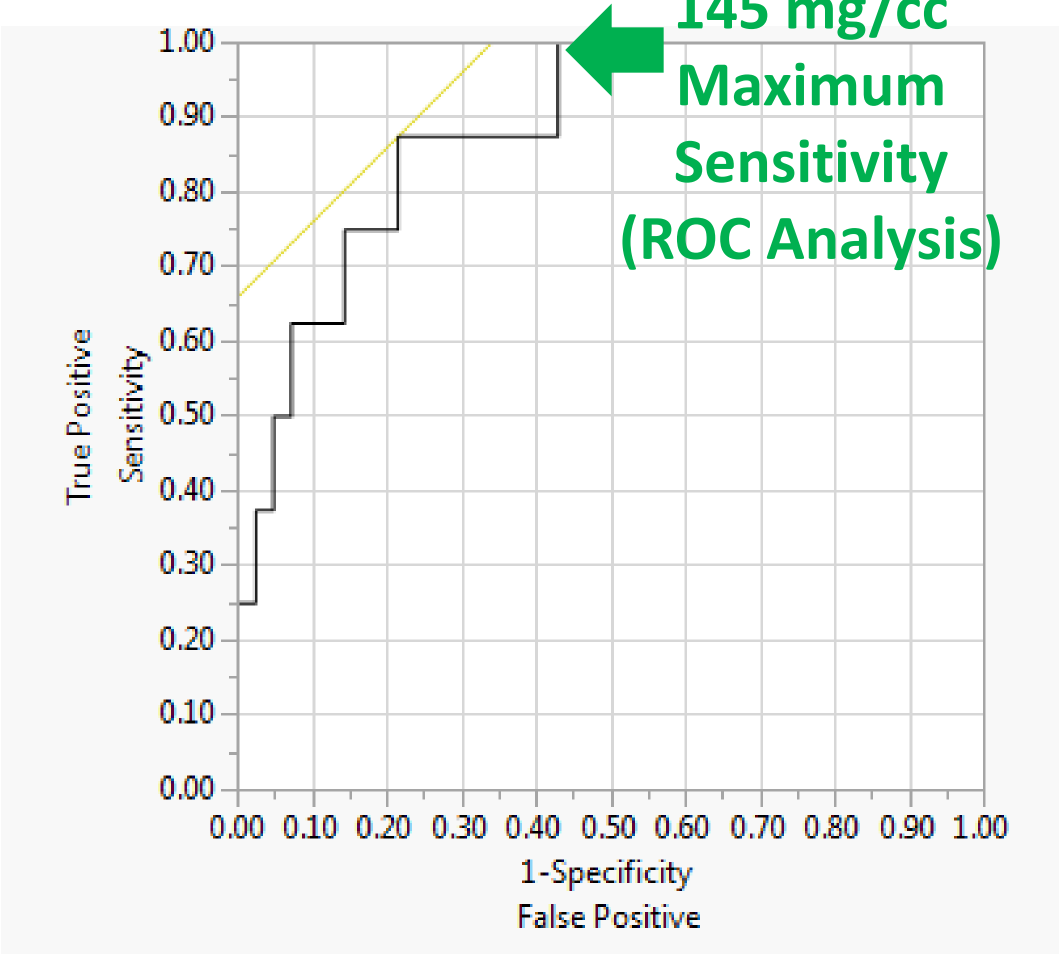
Calibration Method Comparison

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

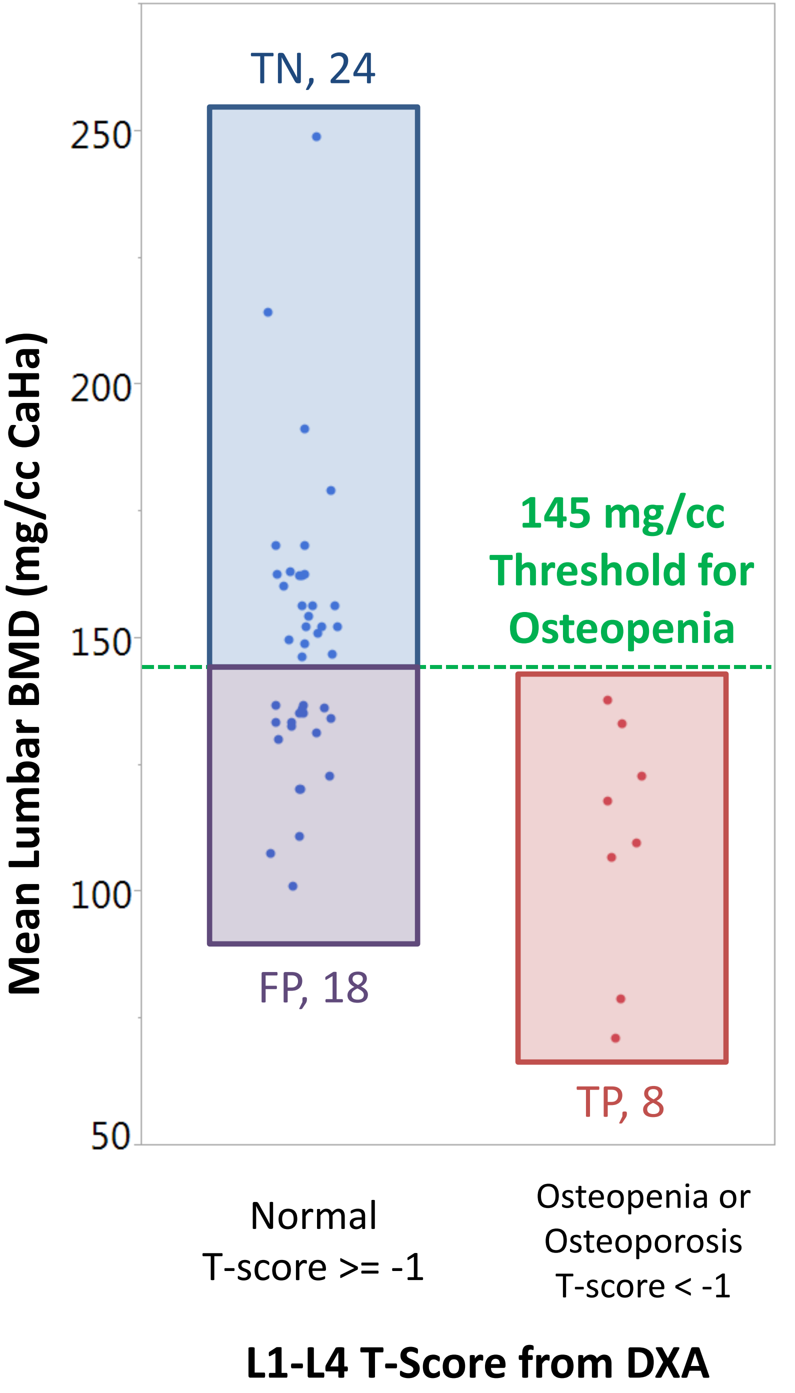


CT-based Predictive mg/cc Threshold for Osteopenia

- DXA/CT, 50 subject pilot data



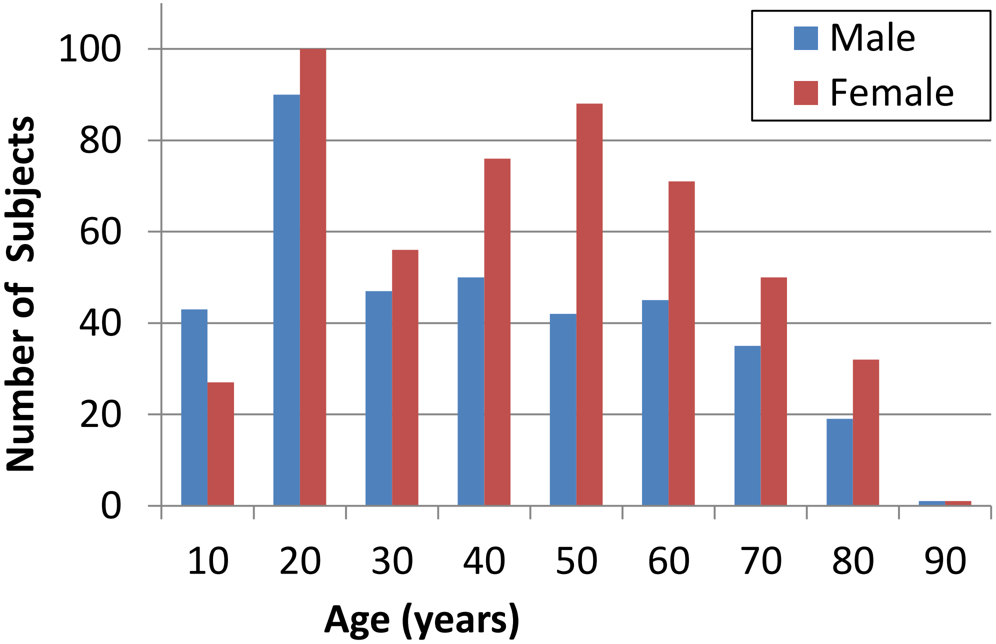
145 mg/cc Maximum Sensitivity (ROC Analysis)



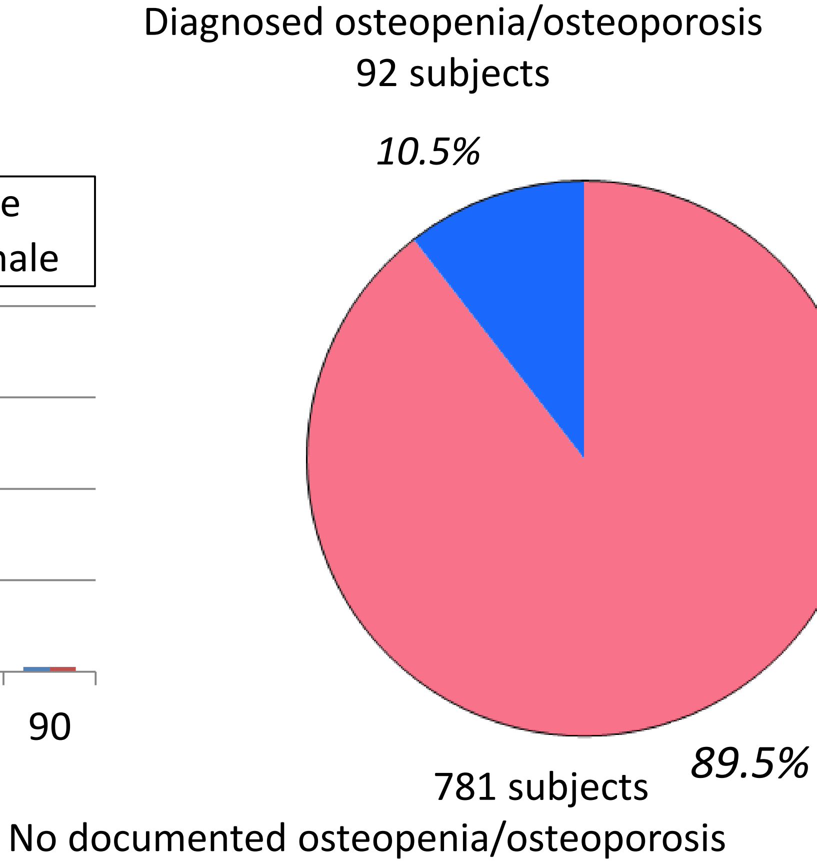
145 mg/cc Threshold for Osteopenia

2015 CIREN Study Population

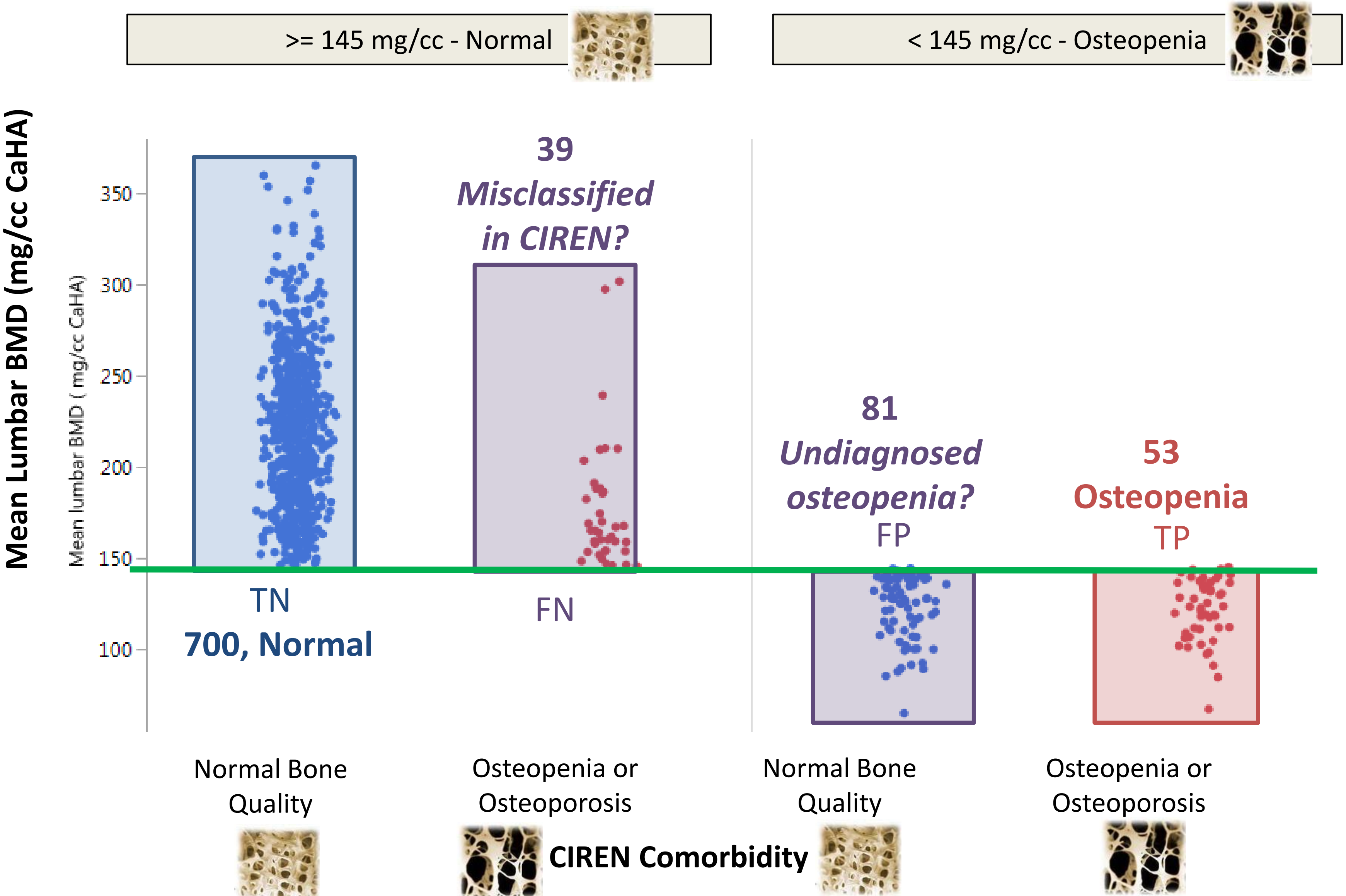
- 873 occupants (372 M, 501 F) across 8 centers
- Abdominal CT
- Ages 16+



CIREN Comorbidities



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



>= 145 mg/cc - Normal

< 145 mg/cc - Osteopenia

39 *Misclassified in CIREN?*

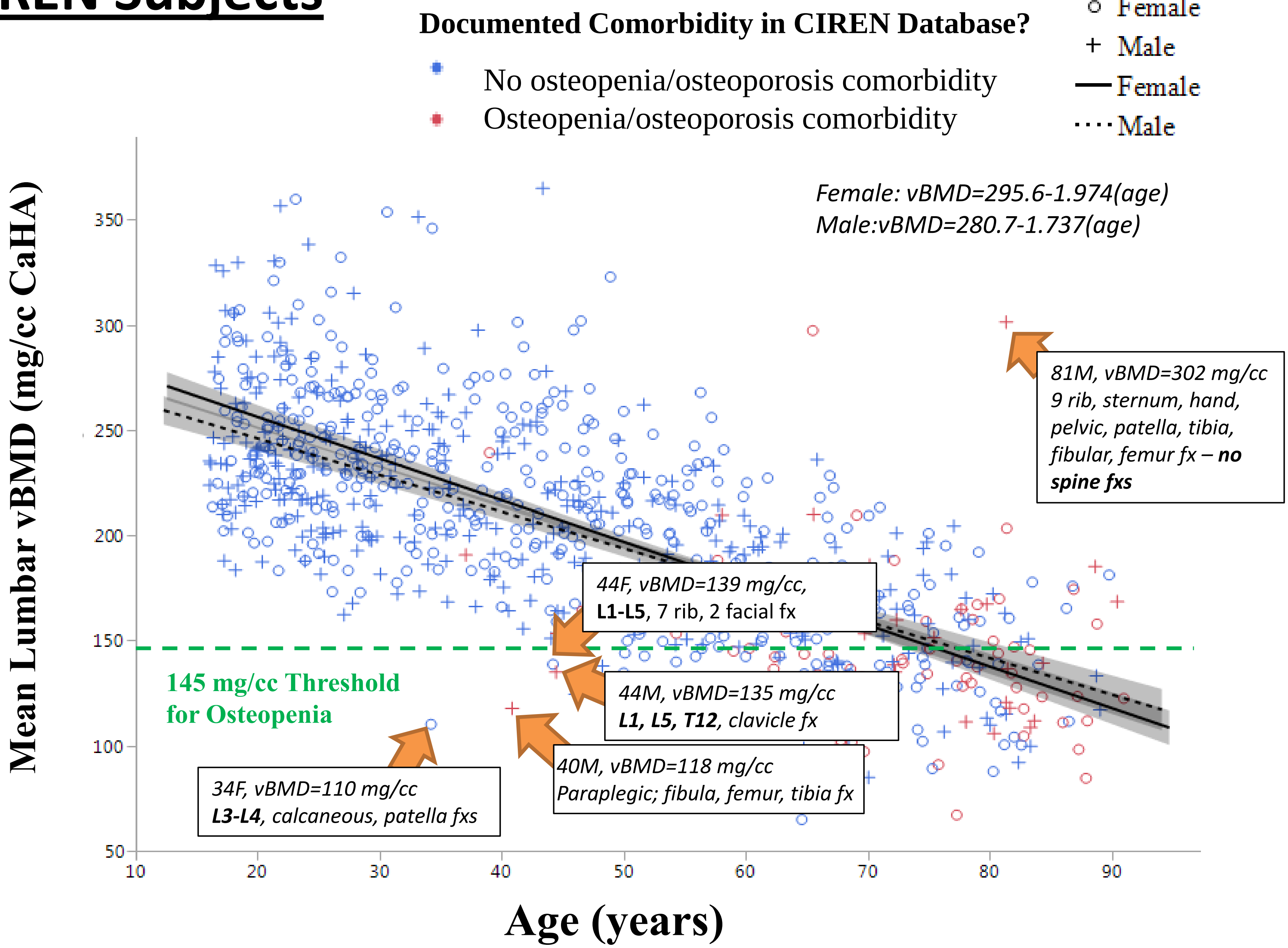
81 *Undiagnosed osteopenia?*
FP

53 Osteopenia
TP

TN
700, Normal

FN

CIREN Subjects



Documented Comorbidity in CIREN Database?

- 🟦 No osteopenia/osteoporosis comorbidity
- 🟥 Osteopenia/osteoporosis comorbidity

○ Female
+ Male
— Female
···· Male

Female: vBMD=295.6-1.974(age)
Male:vBMD=280.7-1.737(age)

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

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

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

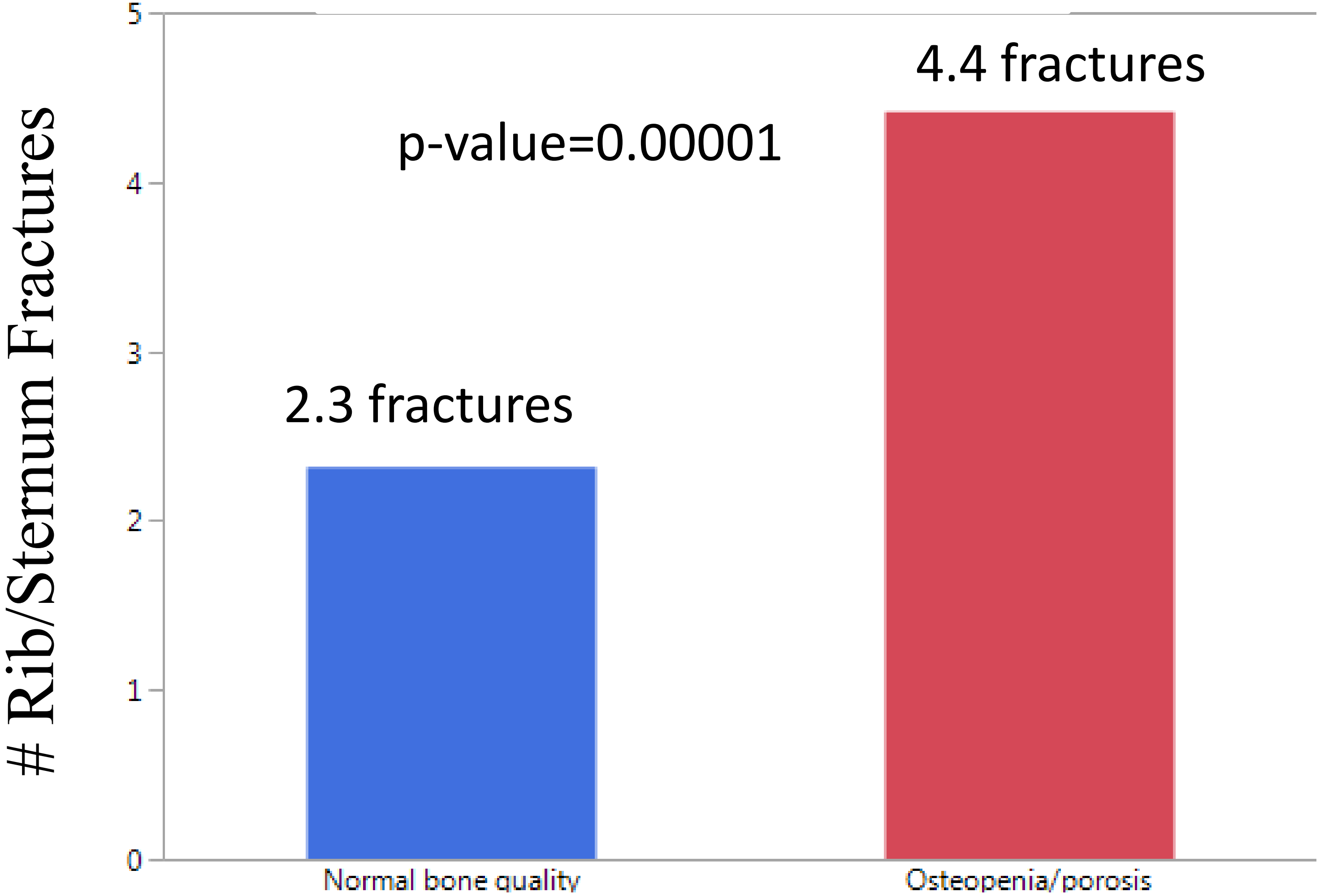
40M, vBMD=118 mg/cc Paraplegic; fibula, femur, tibia fx

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

145 mg/cc Threshold for Osteopenia

Mean Lumbar vBMD (mg/cc CaHA)
350
300
250
200
150
100
50
10
20
30
40
50
60
70
80
90
Age (years)

Significantly Higher # Rib/Sternum Fractures in CIREN Occupants with vBMD < 145 mg/cc



2.3 fractures

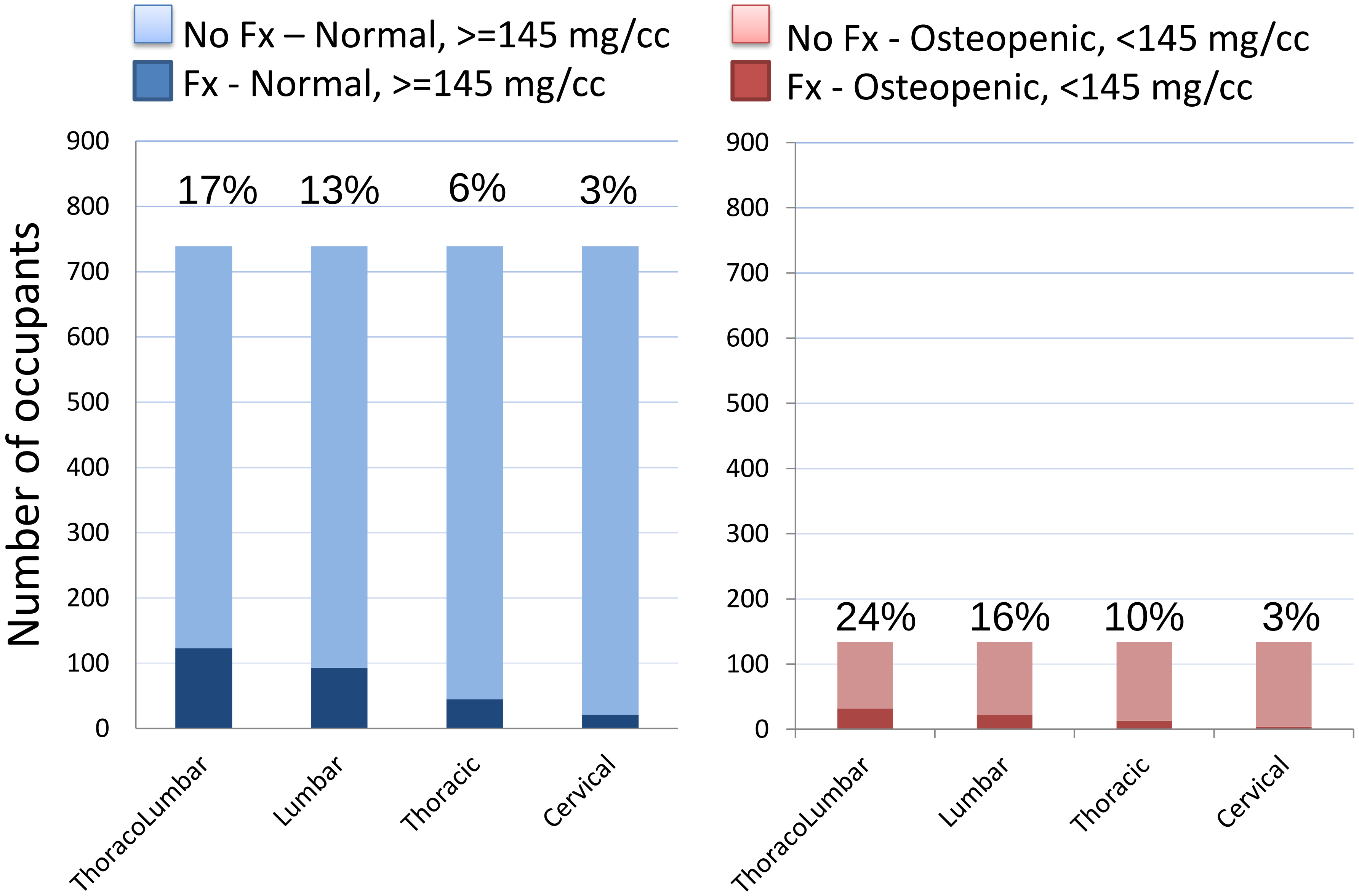
4.4 fractures

p-value=0.00001

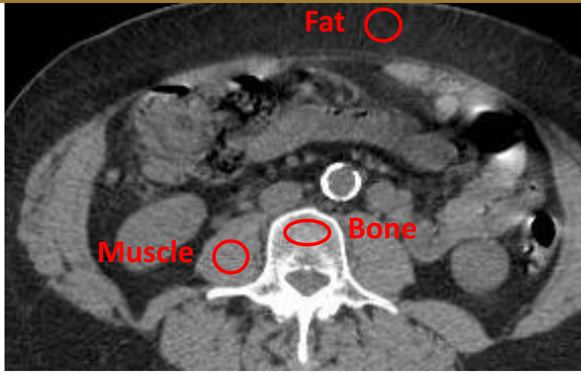
>= 145 mg/cc - Normal

< 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

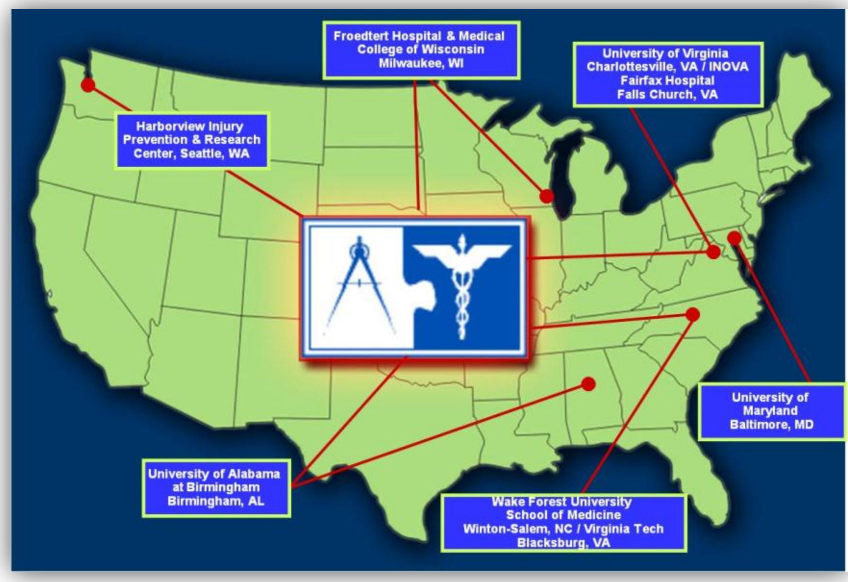
Osteopenia indicated for lumbar BMD<145 mg/cc

- 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

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***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